SD11
A523
#53

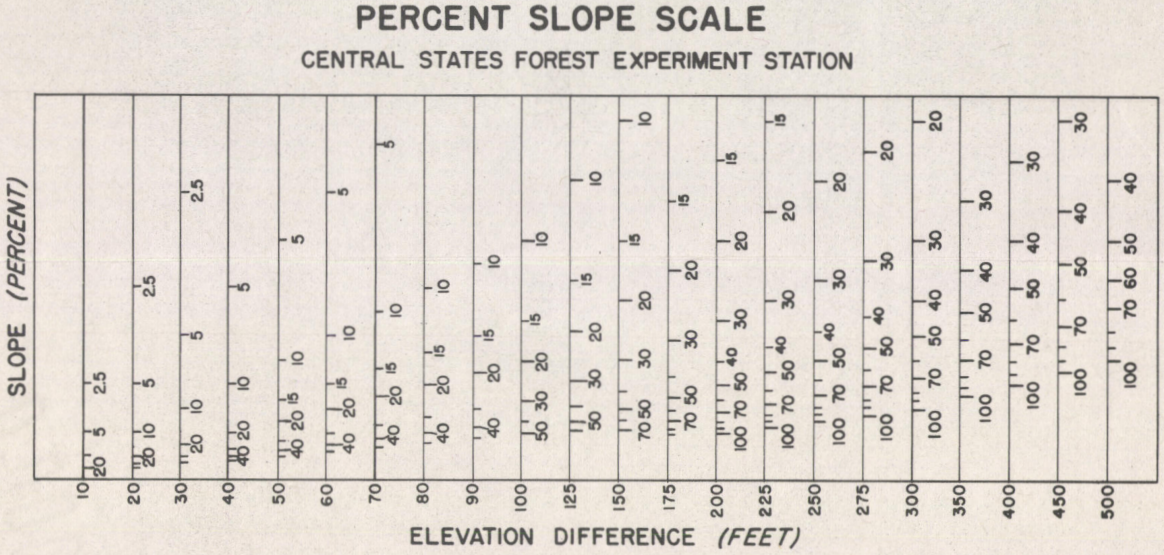
STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 53 April 1949

## A PERCENT SLOPE SCALE FOR PHOTO INTERPRETERS

Land classification procedures, whether developed by foresters or agronomists, are often based on percent of slope. The widespread use of air photos in land-classification surveys suggests the development of a simple technique for determining slope from them. Specially designed parallax wedges[1] have been used to measure slope. This wedge and others following its principle can only be used where the slope is at right angles to the photo flight line. Because of this and other limiting factors the technique is of little practical value.

The percent slope scale (see illustration) permits the measurement of slope percent on air photos regardless of the line of flight. This scale consists of several parallel lines, each representing an elevation difference in feet. The scale units on these individual lines show percent of slope rather than feet. For example, on the 100-foot line the figure 50 is located at a point equal to the horizontal distance required to give a 50 percent slope if the elevation difference is 100 feet. For use the scale is printed on film, and for 1:20,000 photos is approximately one-half the size of the illustration below.


PERCENT SLOPE SCALE
CENTRAL STATES FOREST EXPERIMENT STATION
SLOPE (PERCENT)
ELEVATION DIFFERENCE (FEET)
10 20 30 40 50 60 70 80 90 100 125 150 175 200 225 250 275 300 350 400 450 500

Use--Determine the elevation difference in feet between the upper and lower ends of the slope to be measured. Normally this is

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1/ Spurr, Stephen H., Aerial Photographs in Forestry. 340 pp., illus. New York. 1948. (p. 147)

determined from photos by measurement with the standard parallax wedge or other device. Place the left end of the scale line that corresponds to the measured elevation difference at one end of the slope. At a point opposite the other end of the slope read the percent gradient.

The percent slope scale was tested by measuring 20 slopes distributed through six counties in eastern Kentucky. Slopes varied from 5 to 75 percent. After slope percents had been determined from the air photos, the slopes were measured independently in the field using an Abney level. A statistical analysis of these data indicated that two-thirds of the individual photo measurements made by this technique should be within $\pm$ 14 percent of the field measurement.

Prints of the percent slope scale can be secured through the Engineering Office, U. S. Forest Service, Washington 25, D. C.

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Photo Interpretation Section
Forest Survey

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A5 23
#52

Barney

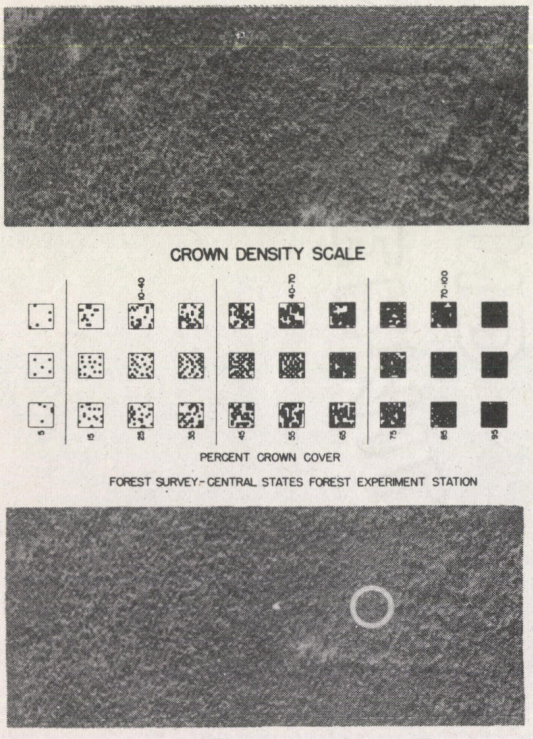
# STATION NOTES

CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 52 March 1949

## A CROWN DENSITY SCALE FOR PHOTO INTERPRETERS

One method of estimating gross volume of timber stands from air photos requires the measurement of tree height, crown diameter, and proportion of area covered by tree crowns. The estimates of this proportion of crown coverage made by trained photo interpreters, using the crown density scale described below, seldom vary by more than 10 percent.




This scale (see fig.) consists of three columns of squares containing black dots that cover from 5 to 95 percent of the area of the squares. The dots in the two outside columns are randomly distributed while those in the center column are mechanically spaced. The area of each square equals one acre at the scale of 1:20,000 photos. At this scale the dots approximate the size of visible crowns of the average mature hardwood tree.

For most effective use, the scales are trimmed on each side close to the figures. The interpreter orients his photo-pair under his stereoscope, and places the scale on the photos perpendicular to the line of flight and between the eyepieces of the stereoscope. He can see the scale in this position, and can also view the photos in stereo. By adjusting the position of the scale, he can determine which square most closely resembles the crown pattern of his plot. The number opposite this square is recorded as the proportion of crown coverage. To assure an accurate determination, care must be taken to compare only tree crowns with scale dots and to discount all shadows.

Prints of the crown density scale can be secured through the Engineering Office, U. S. Forest Service, Washington 25, D. C.

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#51

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STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 51 December 1948

# YOUNG PINE PLANTATION THINNINGS YIELD MERCHANTABLE PRODUCTS

During the spring of 1948, a 13-year-old shortleaf pine plantation on the Kaskaskia Experimental Forest in the southern Illinois uplands was thinned and pruned. The objectives were: to maintain or increase growth of the stand, to concentrate growth on the quality trees left for future harvest, and to determine the volume and value of the first-thinning products.

Before treatment the plantation contained 12.7 cords per acre, representing an average annual growth of almost 1 cord per acre. The average tree was 3.9 inches in diameter at breast height and 26.2 feet tall. The untreated stand contained 1,126 stems per acre, which was reduced to 919 stems by thinning (table 1).

Table 1.--Number of trees and basal area per acre by crown class

| Crown class | Number of trees | | | Basal area, sq. ft. | | |
|---|---|---|---|---|---|---|
| | Original stand | Cut | Residual stand | Original stand | Cut | Residual stand |
| Dominant | 200 | 55 | 145 | 29 | 8 | 21 |
| Codominant | 650 | 145 | 505 | 65 | 16 | 49 |
| Intermediate | 188 | 7 | 181 | 9 | 1 | 8 |
| Suppressed | 88 | 0 | 88 | 2 | 0 | 2 |
| Total | 1,126 | 207 | 919 | 105 | 25 | 80 |

## PLANTATION TREATMENT

Thinning.--The basal area or stocking that will provide optimum quality growth of shortleaf pine plantations in the uplands of southern Illinois must eventually be determined. Research conducted in other regions 1/ 2/ indicates that a basal area of 80 square feet per acre may be a practical minimum for optimum stocking of young southern pine plantations when short-cutting cycles are used. This stocking was used as a guide in thinning the plantations.

Inspection prior to marking the stand for thinning indicated that this level of stocking could be reached and that in the process some marketable

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1/ Averell, James L. Rules of thumb for thinning loblolly pines. Jour. Forestry 43:649-51. 1945.

2/ Ware, L. M., and Stahelin, R. Growth of southern pine plantations at various spacings. Jour. Forestry 46: 267-274. 1948.

products could be harvested. In selecting the trees to be cut, consideration was given to stem and crown spacing, crown position, and form. The better trees in the dominant and codominant crown classes, and practically all of the trees in the intermediate and suppressed classes were left in the plantation. Since the intermediate and suppressed trees occupied only 12.5 percent of the basal area in the thinned stand (table 1), they should not seriously compete with the more important upper-story trees. If the uncut trees in these two classes respond to release, they can be removed in future improvement or harvest cuts. If they do not respond, they will probably die within a few years. Inasmuch as the value of the products obtainable from them seldom equals the cost of harvesting, their natural death thus saves the cost of cutting.

Projection of current growth of the untreated stand, without allowing for subsequent growth acceleration because of treatment indicates that the plantation will contain 135 square feet of basal area in five years. Thus a second thinning should be due before 1953 if only the prethinning growth rate is maintained.

Pruning.--A total of 438 trees in the dominant and codominant crown classes in similar shortleaf pine stands on the Kaskaskia Experimental Forest were pruned to a height of 17 feet. This treatment provided for one clear 16-foot log and left, on the average, about one-third of the live crown. Subsequent measurements on these trees indicate that as much as two-thirds of the live crown can be removed without seriously retarding height and diameter growth.

## PRODUCTS HARVESTED

On a per-acre basis, the 207 cut trees yield 240 marketable fence posts, 7 feet long and 3 inches or larger in diameter. At 5¢ per post, the stumpage value of the harvested trees was $12 per acre, representing a gross earning of almost $1 per acre per year. These same trees contained 3.7 cords of pulpwood per acre. Since local markets for pine pulpwood do not exist, the stumpage value for this product could not be estimated. The stumpage value of products harvested in this thinning probably did not liquidate all costs of the plantation to date. However, this value plus that of the materials to be removed in the next thinning should cover all costs and provide a small profit.

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Kaskaskia Experimental Forest

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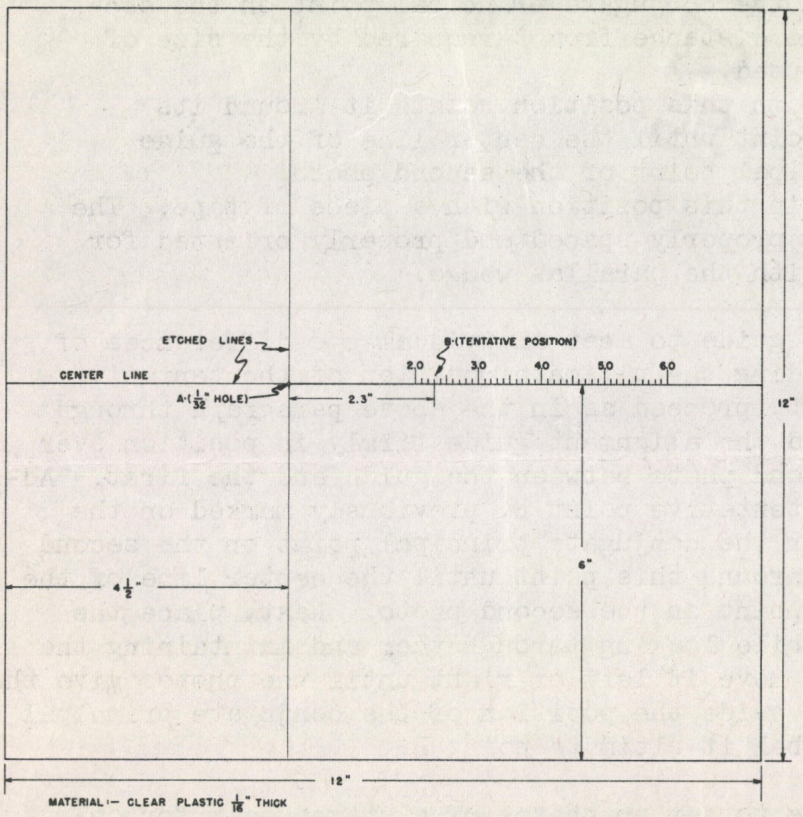
STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 50 December 1948

## AERIAL PHOTO ALIGNMENT GUIDE

Foresters who use aerial photographs will be interested in a mechanical aid that helps to locate photo centers and to align photos of stereo pairs. Photo interpreters who determine tree heights or differences in elevation on aerial photographs by means of the Harvard parallax wedge must have the photos of each stereo pair exactly oriented, and with the centers an exact distance apart. Also, beginners in the stereoscopic use of aerial photographs often have difficulty in placing the photos of a stereo pair in such a position that optimum stereo vision results. The aerial photo alignment guide has been developed to assist the photo interpreter in properly orienting the stereo pair for measurements with the Harvard parallax wedge and to help the beginner orient photos for stereoscopic vision.

Construction.--The construction of the photo alignment guide is a simple process. The only material needed is a 12- by 12-inch sheet of clear plastic 1/16-inch thick. Using a sharp instrument, such as a heavy needle, etch a center line across the under side of the sheet (see fig.). Next, etch a line perpendicular to the first, 4 1/2 inches from one edge. At intersection A make a hole approximately 1/32 inch in diameter. This can be made by using a drill or by forcing a heated needle through the plastic.




To complete the alignment guide for use with the Harvard parallax wedge, etch a scale along the center line, beginning at a point 2 inches from A and continuing to a point 6 inches from A. Graduate the scale in tenths of inches. This scale provides an efficient means of placing photos of a stereo pair the required distance apart. This distance will be equal to the average distance between the two divergent lines on the parallax wedge to be used. This scale also enables the interpreter to determine the air-base distance, which is the distance between the two photo centers as shown on either photo. The air-base distance is needed when determining differences in elevation or height of trees.

To complete the alignment guide for beginners' use as an aid in placing the photos of a stereo pair in position for best stereo vision, mark in pencil on the center line the tentative position of point B. An average distance of 2.3 inches between points A and B serves for most people. A procedure for further adjusting for individual eye-differences of beginners is explained in the next section.

Use.--A few simple steps to aid in the use of the alignment guide with the parallax wedge are:

1. To find the principal point (center) of any photo, place the alignment guide over it so that the two lines of the guide fall exactly on the points of the fiducial marks (four arrows) found on the photo edge. The principal point will be beneath intersection A.
2. Mark the principal point of each photo of a stereo pair by pricking with a needle through the hole at A.
3. Next, mark the conjugate principal point on each photo. The conjugate principal point is the position of the principal point of one photo as it falls on the adjacent photos. For accurate work use the stereoscope in transferring these points.
4. Place the first photo in a fixed position on the table with a piece of tape.
5. Adjust the alignment guide over this photo until point A falls over the principal point and the center line of the guide passes over the conjugate principal point.
6. Hold the alignment guide firmly in position with the left hand and with the other slip the second photo between the guide and the first photo until the conjugate principal point on the second photo rests at the distance from A required by the size of parallax wedge being used.
7. With the second photo in this position rotate it around its conjugate principal point until the center line of the guide passes over the principal point of the second photo.
8. Fix the second photo in this position with a piece of tape. The photo centers are now properly spaced and properly oriented for making measurements with the parallax wedge.

Further adjustment of the guide to meet individual eye-differences of beginners is accomplished by finding the ultimate position of the tentative point B. To make this adjustment, proceed as in the above paragraph through step number five. As above, hold the alignment guide firmly in position over the first photo and slip the second photo between the guide and the first. Adjust the second photo until the tentative point B, previously marked on the center line of the guide, is over the conjugate principal point on the second photo. Rotate the second photo around this point until the center line of the guide passes over the principal point on the second photo. Next, place the stereoscope over the guide and while looking through them and maintaining the orientation of the second photo, move it left or right until the photos give the best stereo vision. Mark on the guide the position of the conjugate principal point of the second photo and label it ultimate point B.

To use the alignment guide to set up photos of a stereo pair for optimum stereo vision, proceed as in the eight directions given above, except that in step six, place the conjugate principal point of the second photo under ultimate point B.

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STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 49 December 22, 1948

## TREE DEFECTS COMMON IN THE UPLAND FORESTS OF SOUTHERN ILLINOIS

Nearly 75 percent of the trees in the upland forests of southern Illinois were defective in 1936. Fire scars and branch stubs were the most frequent causes of defect. Twenty-two percent of the total volume of the defective trees was cull (table 1).

Table 1.--Proportion of trees in the upland forests of southern Illinois that were defective together with cull percents

PERCENT OF ALL SAMPLE TREES

| Species | Kind of defect | | | | | | Trees without defect |
|---|---|---|---|---|---|---|---|
| | Butt rot: Fire | Butt rot: Other | Branch stubs | Insects | Miscellaneous 1/ | Total | |
| White oak | 35 | 5 | 7 | 2 | 6 | 55 | 45 |
| Black oak | 38 | 6 | 26 | 7 | 11 | 88 | 12 |
| Scarlet oak | 12 | 6 | 25 | 21 | 7 | 71 | 29 |
| Other oaks | 38 | 3 | 6 | 3 | 23 | 73 | 27 |
| Yellow-poplar | 52 | 19 | 0 | 0 | 15 | 86 | 14 |
| Hickory | 65 | 3 | 0 | 0 | 3 | 71 | 29 |
| Miscellaneous | 50 | 5 | 30 | 0 | 0 | 85 | 15 |
| All trees | 36 | 6 | 16 | 7 | 8 | 73 | 27 |

CULL PERCENT OF TOTAL CUBIC VOLUME OF DEFECTIVE TREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| All trees | 5 | 2 | 7 | 1 | 7 | 22 | -- |

1/ Includes felling injuries, lightning damage, frost cracks, heart check, wind shake, and others.

The above data are based on measurements of the stems of 487 trees to determine the occurrence of tree defects, the principal kinds, and the agents causing them.1/ The sample trees were cut from three 1-acre plots located in the mixed upland hardwood forests of southern Illinois. In addition, the trees removed in a 20-acre commercial operation were studied.

1/ Field work was completed in 1936 by John G. Kuenzel, Central States Forest Experiment Station and personnel of the Shawnee National Forest. Decay agents were identified by the Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering.

Cull percents:--The percent of gross volume of all sample trees culled because of defect is summarized in table 2. These cull percents have local value only, but are a good indication of the volume of material affected by the various kinds of defect.

Table 2.--Cull percents by species and diameter class1/

| Species | Small poles 3.6-7.5 inches | Large poles 7.6-11.5 inches | Sawtimber 11.6 inches + |
|---|---|---|---|
| | -Percent of gross volume- | | |
| White oak | 8.4 | 19.6 | 16.7 |
| Black oak | 3.0 | 29.5 | 16.8 |
| Scarlet oak | 11.4 | 20.1 | 23.8 |
| Other oaks | -- | -- | 22.9 |
| Yellow-poplar | 12.1 | 6.0 | 8.3 |
| Hickory | 29.1 | 25.6 | 26.5 |
| Miscellaneous | -- | -- | 23.3 |

1/ Diameter at 4 1/2 feet above ground.

Decay agents:--To determine the agents responsible for decay, 306 samples of decayed wood were examined. From them 119 pure cultures were made and seven genera of fungi were found. In order of their frequency, they were Stereum sp., Polyporous sp., Poria sp., Fomes sp., Hydnum sp., Corticum sp., and Armillaria sp. A few others occurred but were not identified.

Forest fire history:--Analysis of fire scars on the sample trees indicated that the earliest fire on the study areas occurred in the season 1734-35. Bad fire years occurred during the seasons of 1884-85, 1894-95, 1914-15, 1923-24 and 1929-30. The scars also showed that fires occurred in all but two years during the period 1906-1935.

Although this study was completed in 1936, the proportion of defective trees in the upland forests of southern Illinois has decreased only slightly. In the main, stands have not been managed or protected from fire. On those areas where fire has been practically eliminated, such as the Shawnee National Forest and state forests, damage to the older trees has been reduced, and dense young stands of desirable species have developed. Protection of all forest areas from fire and grazing will greatly reduce the defective volume in forests of the future. Early removal of defective trees plus management for a clean, vigorous forest will reduce defects resulting from branch stubs, insects, and other causes.

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STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 48 December 1948

## DOT-TYPE SCALE FOR MEASURING TREE-CROWN DIAMETERS ON AERIAL PHOTOGRAPHS

The gross volume of timber stands can be estimated from aerial photographs by measuring crown diameter, tree height, and crown density. The crown wedge (fig. 1) is commonly used to measure crown diameter. The wedge, etched on transparent material, is moved over the photographic image of the tree crown to be measured until the edges of the crown just touch the converging lines of the wedge. At this point the scale on the lower wedge line is read to determine the crown diameter on the photograph in hundredths of an inch. The actual diameter of the tree crown can then be determined by reference to conversion tables (table 1).

As the wedge lines converge, the crown perimeters on the photograph blend with them making measurement difficult, and actually impossible where the wedge lines appear to consolidate for a short distance before they converge. Increased accuracy at the narrow end of the wedge is important where aerial photographs have a scale of approximately 1:20,000. At this scale even the images of large crowns appear as very small dots and must be measured at the small end of the wedge. Use of the wedge to measure crowns of irregular shape is particularly difficult. The crown diameter must be measured from several directions and averaged to obtain a reading that is representative of the area of the jagged image presented. Furthermore, some interpreters have difficulty in learning to use the wedge.

To overcome some of these disadvantages, the dot-type crown scale was devised (fig. 2). It allows side-by-side comparison of the dots of different sizes with the photographic image of the crown whose diameter is to be determined. No complicating wedge lines are involved. Very small crowns are readily measured. Visual comparison of crown area, regardless of shape, with a dot seems to be a relatively simple and accurate operation.

The consistency of readings made with the dot-type crown scale was compared with that of the wedge. Three interpreters used the dot-type scale to determine average crown size of trees on each of 168 saw-timber plots which had previously been measured by three interpreters applying the crown wedge. The consistency of reading proved slightly greater for the dot-scale than for the wedge. The dot-type scale is therefore recommended in preference to the crown wedge, where small-scale photographs are used.

Chester E. Jensen, Forester
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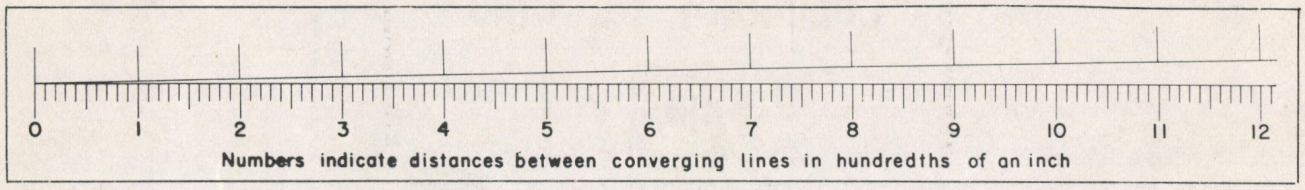


Fig. 1.--Crown wedge

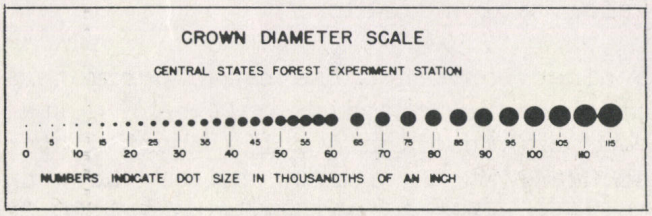
CROWN DIAMETER SCALE
CENTRAL STATES FOREST EXPERIMENT STATION
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115
NUMBERS INDICATE DOT SIZE IN THOUSANDTHS OF AN INCH

Fig. 2.--Dot-type crown scale

Table 1.--Actual crown width for various photo-crown widths and photo scales

| Photo Crown Width : | 1:18,000 | 1:19,000 | 1:20,000 | 1:21,000 | 1:22,000 |
|---|---|---|---|---|---|
| Thousandths of an inch | Feet | Feet | Feet | Feet | Feet |
| 2.5 | 4 | 4 | 4 | 4 | 5 |
| 5.0 | 7 | 8 | 8 | 9 | 9 |
| 7.5 | 11 | 12 | 13 | 13 | 14 |
| 10.0 | 15 | 16 | 17 | 18 | 18 |
| 12.5 | 19 | 20 | 21 | 22 | 23 |
| 15.0 | 22 | 24 | 25 | 26 | 27 |
| 17.5 | 26 | 28 | 29 | 31 | 32 |
| 20.0 | 30 | 32 | 33 | 35 | 37 |
| 22.5 | 34 | 36 | 37 | 39 | 41 |
| 25.0 | 37 | 40 | 42 | 44 | 46 |
| 27.5 | 41 | 44 | 46 | 48 | 50 |
| 30.0 | 45 | 47 | 50 | 53 | 55 |

The crown-width conversion table can be readily computed for use with photos of a scale other than those given above.

Log scale Scribner rule

| Top d.i.b. | Log length - feet | | | | |
|---|---|---|---|---|---|
| | 8 | 10 | 12 | 14 | 16 |
| Inches | Board feet | | | | |
| 8 | 15 | 19 | 22 | 26 | 30 |
| 10 | 28 | 34 | 41 | 48 | 55 |
| 12 | 43 | 54 | 64 | 75 | 86 |
| 14 | 62 | 77 | 92 | 108 | 123 |
| 16 | 83 | 104 | 124 | 145 | 166 |
| 18 | 108 | 135 | 162 | 189 | 216 |
| 20 | 136 | 170 | 204 | 238 | 272 |
| 22 | 167 | 209 | 250 | 292 | 334 |
| 24 | 202 | 252 | 302 | 353 | 403 |
| 26 | 239 | 299 | 358 | 418 | 478 |
| 28 | 280 | 349 | 419 | 489 | 559 |
| 30 | 324 | 404 | 485 | 566 | 647 |
| 32 | 370 | 463 | 556 | 648 | 741 |
| 34 | 420 | 526 | 631 | 736 | 841 |
| 36 | 474 | 592 | 711 | 830 | 948 |
| 38 | 530 | 663 | 796 | 928 | 1,061 |
| 40 | 590 | 738 | 885 | 1,032 | 1,180 |



Log scale Doyle rule

| Top d.i.b. | Log length - feet | | | | |
|---|---|---|---|---|---|
| | 8 | 10 | 12 | 14 | 16 |
| Inches | Board feet | | | | |
| 8 | 8 | 10 | 12 | 14 | 16 |
| 10 | 18 | 22 | 27 | 32 | 36 |
| 12 | 32 | 40 | 48 | 56 | 64 |
| 14 | 50 | 62 | 75 | 88 | 100 |
| 16 | 72 | 90 | 108 | 126 | 144 |
| 18 | 98 | 122 | 147 | 172 | 196 |
| 20 | 128 | 160 | 192 | 224 | 256 |
| 22 | 162 | 202 | 243 | 284 | 324 |
| 24 | 200 | 250 | 300 | 350 | 400 |
| 26 | 242 | 302 | 363 | 424 | 484 |
| 28 | 288 | 360 | 432 | 504 | 576 |
| 30 | 338 | 422 | 507 | 592 | 676 |
| 32 | 392 | 490 | 588 | 686 | 784 |
| 34 | 450 | 562 | 675 | 788 | 900 |
| 36 | 512 | 640 | 768 | 896 | 1,024 |
| 38 | 578 | 722 | 867 | 1,012 | 1,156 |
| 40 | 648 | 810 | 972 | 1,134 | 1,296 |

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STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

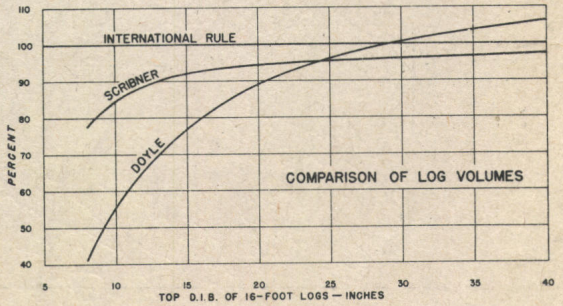
No. 47 October 1, 1948

FOREST SERVICE
OCT 21 1948
RESEARCH
No. 0.73

LOG RULE COMPARISON

INTERNATIONAL 1/4-INCH, DOYLE, AND SCRIBNER

Both the Doyle and Scribner log rules consistently underscale logs smaller than 22 inches in diameter, whereas board-foot volumes by the International 1/4-inch rule closely approximate lumber tally. The following chart and tables show the volume relationships between the three log rules and provide factors for converting log volumes and values from one rule to another. Because the International rule more nearly approximates mill tally, it has been used as the standard for comparison.



## Comparison of Doyle and Scribner log volumes with International

| Top d.i.b. | 8-ft. logs | | 10-ft. logs | | 12-ft. logs | | 14-ft. logs | | 16-ft. logs | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Doyle | Scrib. | Doyle | Scrib. | Doyle | Scrib. | Doyle | Scrib. | Doyle | Scrib. |
| Inches | Percent | | | | | | | | | |
| 8 | 47 | 88 | 45 | 84 | 44 | 81 | 42 | 79 | 41 | 77 |
| 10 | 62 | 96 | 60 | 90 | 59 | 88 | 57 | 86 | 55 | 85 |
| 12 | 73 | 98 | 71 | 96 | 69 | 93 | 67 | 90 | 66 | 89 |
| 14 | 79 | 98 | 78 | 96 | 77 | 94 | 75 | 92 | 74 | 90 |
| 16 | 86 | 99 | 83 | 97 | 82 | 95 | 81 | 93 | 80 | 92 |
| 18 | 90 | 99 | 88 | 97 | 87 | 96 | 86 | 94 | 84 | 93 |
| 20 | 93 | 99 | 92 | 98 | 91 | 97 | 90 | 95 | 88 | 94 |
| 22 | 96 | 99 | 95 | 98 | 94 | 97 | 93 | 95 | 92 | 94 |
| 24 | 99 | 99 | 97 | 98 | 96 | 97 | 95 | 96 | 94 | 95 |
| 26 | 100 | 99 | 99 | 98 | 99 | 97 | 98 | 96 | 97 | 95 |
| 28 | 102 | 99 | 101 | 98 | 100 | 97 | 99 | 96 | 99 | 96 |
| 30 | 104 | 99 | 103 | 98 | 102 | 98 | 101 | 97 | 100 | 96 |
| 32 | 105 | 99 | 104 | 99 | 104 | 98 | 103 | 97 | 102 | 96 |
| 34 | 106 | 99 | 105 | 99 | 105 | 98 | 104 | 97 | 103 | 96 |
| 36 | 107 | 99 | 107 | 99 | 106 | 98 | 105 | 97 | 104 | 97 |
| 38 | 108 | 99 | 107 | 99 | 107 | 98 | 106 | 97 | 105 | 97 |
| 40 | 109 | 99 | 108 | 99 | 107 | 98 | 106 | 97 | 106 | 97 |



Log volumes and values in terms of one rule can be converted to another by means of the above percentages, using the following procedures:

1. To convert International volume to Doyle or Scribner, multiply the International volume by the percentage for the desired rule, log diameter and length. Example: Given 1,000 board feet International volume in 14-inch logs 12 feet long, what is the Doyle volume? 1,000 x 0.77 (from table) = 770 board feet Doyle volume.

2. To convert Doyle or Scribner volume to International, divide the Doyle or Scribner volume by the percentage for the given rule, log diameter and length. Example: Given 1,000 board feet Doyle volume in 16-inch logs 10 feet long, what is the International volume? 1,000 ÷ 0.83 = 1,205 board feet International volume.

3. Doyle volume can be converted to Scribner volume, or vice versa, by first changing to International and then to the desired rule, using the above procedures. Example: Given 1,000 board feet Doyle volume in 16-inch logs 10 feet long, what is the Scribner volume? Doyle volume = 1,205 board feet International (see 2 above); then 1,205 x 0.97 = 1,169 board feet Scribner volume.

4. Dollar values per unit volume in terms of one rule can be converted to another rule substituting dollar values for log volumes in the above procedures and by dividing where multiplying is indicated and vice versa. Example: Given a number of logs 16 inches in diameter and 12 feet long, worth $100.00 per thousand board feet International scale, what is the Doyle value per thousand board feet? $100.00 ÷ 0.82 (from table) = $121.95.



## Log scale International 1/4" rule

| Top d.i.b. | Log length - feet | | | | |
|---|---|---|---|---|---|
| | 8 | 10 | 12 | 14 | 16 |
| Inches | Board feet | | | | |
| 8 | 17 | 22 | 27 | 33 | 39 |
| 10 | 29 | 38 | 46 | 56 | 65 |
| 12 | 44 | 56 | 69 | 83 | 97 |
| 14 | 63 | 80 | 98 | 117 | 136 |
| 16 | 84 | 108 | 131 | 156 | 181 |
| 18 | 109 | 139 | 169 | 200 | 232 |
| 20 | 137 | 174 | 211 | 250 | 290 |
| 22 | 168 | 214 | 259 | 306 | 354 |
| 24 | 203 | 257 | 311 | 368 | 424 |
| 26 | 241 | 304 | 368 | 434 | 501 |
| 28 | 281 | 356 | 430 | 507 | 584 |
| 30 | 325 | 411 | 497 | 586 | 674 |
| 32 | 373 | 470 | 568 | 669 | 770 |
| 34 | 423 | 534 | 644 | 758 | 872 |
| 36 | 476 | 600 | 725 | 853 | 981 |
| 38 | 533 | 672 | 811 | 954 | 1,096 |
| 40 | 593 | 752 | 912 | 1,065 | 1,218 |

d.i.b. = diameter inside bark

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STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 46 June 1948

# PLANTED BLACK LOCUST ON CLAYPAN SOILS OF SOUTHERN ILLINOIS

During the period 1936 to 1938 a company planted about 100 acres of black locust on claypan lands in Franklin County, Illinois. Since 1947 most of these plantations have been clear-cut and the areas planted to shortleaf pine. The locust was stagnated, broken, riddled with borers, and many trees were dead. Hardly a single good post or prop per acre had been produced or could be expected (See Fig. 1 on next page). The company decided to clear the land (See Fig. 2), and plant it to a species for which it is better suited.

Only a word is necessary to explain why black locust failed. The areas planted are nearly flat and have a claypan soil which consists of a thin layer of gray or yellowish-gray, strongly leached topsoil resting on an almost impervious subsoil of light gray clay. On the plantation sites the light gray, impermeable subsoil is about 12 inches below the surface. A few crawfish holes are present, and these alone are reliable indicators of an impermeable subsoil and poor internal drainage. The dark-colored topsoil is about 5 inches thick in the plantations. Both the surface soil and subsoil are highly acid, the pH ranging from 4.5 in the subsoil to 5.5 in the surface layer. Soils of this kind extend in a broad band across southern Illinois generally between U. S. Highway 40 and State Highway 13, and into southwestern Indiana.

The above description shows that nearly every soil requirement of black locust is absent on the planting areas. To succeed, black locust plantings should be made on deep, well-aerated, reasonably "sweet" soil with good internal drainage. The claypan soils are not ideal for any tree species, but evidence indicates that shortleaf or loblolly pine would at least make mine props.1/

The 10 to 12 years of locust growth had some good effects on the site. The most noticeable was the greater looseness and friability of the topsoil and the rather rank growth of weeds and briars (See Fig. 1). The pH was raised one-half to one point above that of adjacent open fields and nearby pine plantations. The topsoil seemed slightly deeper under the locust but data were insufficient to justify a conclusion.

The conversion to pine cost about $50.00 per acre. To this must be added the original cost of the locust planting, the carrying charges on land and investment for 12 years, and the loss of locust production for 12 years. The total indicates a very expensive job of land-management correction, and shows in a vivid way how inadequate information regarding site requirements of species can result in a real cash loss.

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1/ Planted Pines on Claypan Soils of Southern Illinois, Central States Forest Experiment Station Note No. 44.

Figure 1. Black locust plantation 12 years after planting. This plantation has no value except for firewood. Impervious clay-pan is only 12 inches below surface.

Figure 2. Land after clearing the planted locust, burning brush, and disking. This area will now be planted to shortleaf pine. Additional clearing is being done in background.

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STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 45 June 1948

## SHIPMAST VS. COMMON BLACK LOCUST IN SOUTHERN ILLINOIS

In March 1935, 1-year-old black locust stock was planted on a nearly level upland old field on the Shawnee National Forest in southern Illinois. One-half of the planting stock was from local seed, and the remainder from root cuttings of Long Island shipmast locust. Shipmast is a strain of black locust found on Long Island where it is characterized by superior stem form. The local seed was from the best natural stand of common black locust that could be found.

An examination of the planting area during March 1948 showed no important differences in form or growth between trees from the two sources. The summarized results given below are based upon three plots, each having 84 planted trees from each of the two sources.

| | Shipmast locust | Common locust |
|---|---|---|
| Mean height, feet | 31.4 | 30.7 |
| Mean d.b.h., inches | 3.7 | 3.6 |
| Trees unforked below 16 feet, percent | 44.6 | 42.3 |
| Trees forked 2 feet or less from ground, percent | 31.3 | 38.5 |
| Survival, percent | 73.0 | 60.7 |

A test of the effect of top-pruning at the time of planting on tree height, percent survival, and forming of the main stem showed no significant results for either shipmast or common locust. The data for both shipmast and common locust combined are summarized below.

| | Top-pruned | Unpruned |
|---|---|---|
| Mean height, feet | 31.6 | 30.7 |
| Survival, percent | 67.9 | 65.5 |
| Trees unforked below 16 feet, percent | 45.0 | 43.0 |

The growth and form of Long Island shipmast locust, when planted in the uplands of southern Illinois, is not superior to common black locust. The slightly better survival may or may not have been due to the strain. It could have been caused by the relative condition of the planting stock or by the different type of stock used; i.e., root-cutting stock vs. seedling stock.

Perhaps the most pertinent general conclusion is that superior strains of trees transported to places of greatly different climate and soil may not reproduce their desirable characteristics. Probably the most desirable way to obtain better trees is to use the best native stock as a base, and through selection and hybridization develop a superior strain adapted to the local climate and soil.

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STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 44 June 9, 1948

# PLANTED PINES ON CLAYPAN SOILS OF SOUTHERN ILLINOIS

Shortleaf, loblolly, pitch, and Virginia pine were planted in April, 1940, on an eight-acre area along State Highway 37 two miles north of West Frankfort, Illinois. The planting was made by the Chicago, Wilmington, and Frankfort Coal Co. in cooperation with the Central States Forest Experiment Station. Half the planting stock of each species was 1-0 seedlings and half 1-1 transplants.

Shortleaf pine planted eight years. Virginia pine and pitch pine of same age are at extreme right and left, respectively.

The planting site is a nearly flat area typical of the broad belt of claypan soils which, in southern Illinois, lie chiefly between U. S. Highway 40 and State Highway 13. Similar soils are also present in southwestern Indiana and Northern Missouri. Typical claypan areas have a thin layer of gray or yellowish-gray, strongly leached soil resting on an almost impervious subsoil of light gray clay. Their poor internal drainage causes extreme wetness in the winter and spring, extreme dryness during the summer, and high soil acidity. On the plantation area

the average depth to the claypan is 12 inches and the darker colored topsoil is less than 5 inches deep. Soil acidity was pH 4.0 to 4.5 for the claypan layer and 5.0 for the topsoil.

Eight years after planting, survival is more than 85 percent for all species. Stand heights average approximately 20 feet for loblolly pine, 13 feet for shortleaf pine, 12 feet for pitch pine, and 10 feet for Virginia pine. Heights of trees of a given species are uniform and very little expression of dominance is shown. The 4- by 6-foot spacing and good survival have given a dense stand that will need early thinning to avoid stagnation.

Only pitch pine showed an appreciable difference between trees grown from 1-1 and 1-0 stock. The stand grown from 1-1 stock is now about 14 feet high and has over 90 percent survival. The stand from 1-0 stock is about 11 feet tall and has approximately 70 percent survival.

This coal company, as well as others in the claypan section of southern Illinois, is planting pine for mine props. Some farmers may wish to plant for fence posts, props, or other small timbers. The following preliminary but practical lessons can be learned from this pine planting on the claypan soils of southern Illinois:

1. Virginia and pitch pines will survive and grow, but because of excessive branching and crook have a low value for anything except game and ground cover, and possibly Christmas trees.

2. Loblolly pine survives well and grows the fastest but is subject to bending and breaking by snow and ice. The dead branches tend to persist. It is farther removed from its natural range than shortleaf pine, and consequently its future behavior is less certain.

3. Shortleaf pine is the straightest, prunes the best, and is little subject to snow and ice damage. It survives well but does not grow as fast as loblolly pine. Until more information is available, shortleaf pine should probably be planted for mine props in preference to other pine species.

4. The 4- by 6-foot spacing gave an overly dense stand. Spacing of 6- by 6-, 7- by 7-, or 6- by 8-feet would have been better.

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STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 43 May 1948

## PRELIMINARY REPORT OF YIELDS OF LUMBER BY GRADES FROM IOWA TIMBER

Grade 1 saw logs, cut from Iowa timberlands, yield 2½ times as much No. 1 Common and better lumber as Grade 3 logs. A study by the Forestry Section, Iowa Agricultural Experiment Station, in cooperation with the Central States Forest Experiment Station, emphasizes this marked difference. The study was made from 1943 to 1945 with the objectives of grading logs and of finding out the average proportions of lumber grades sawn from each log grade.

Logs were graded on the basis of diameter, length, surface appearance, and defects. Grade 1 logs had to be 12 inches or larger in diameter, 10 feet or longer in length, practically clear and straight. Grade 2 logs were 10 inches and larger, 8 feet and longer, and allowed a few knots and other defects. Grade 3 logs were 8 inches and larger, 6 feet and longer and allowed more defects.

The log grading showed that about 17 percent of the number of logs brought to the sawmills were Grade 1; about 38 percent, Grade 2; and about 45 percent, Grade 3. Of some 1200 logs followed through the mills, about 85 percent were white elm, cottonwood, and northern red oak. These three species comprise about 58 percent of Iowa's annual lumber production. All of them showed a low proportion of Grade 1 logs. Cottonwood, with almost 22 percent of Grade 1 logs, was the best of the three.

Grade 1 elm logs yield about 65 percent No. 1 Common and better lumber. Cottonwood yields 69 percent and northern red oak 76 percent (See Table on Page 2). Of these yields 30 to 34 percent is Firsts and Seconds (FAS). By contrast, Grade 2 logs of the three species yield 48 to 54 percent No. 1C and better, of which only 8 to 10 percent is FAS. Grade 3 logs return 20 to 35 percent No. 1C and better, of which only 2 to 3 percent is FAS. When the logs for all three species are combined, as in the last portion of the table, Grade 1 logs show about 70 percent No. 1C and better in contrast to about 28 percent for Grade 3 logs.

When each species is considered by itself on a mill-run of logs, cottonwood is best with a yield of 55 percent No. 1C and better lumber. White elm comes second with 46 percent, and northern red oak yields 42 percent No. 1C and better.

A higher proportion of Grade 1 saw logs in Iowa's timberlands would increase the value, demand, and market for Iowa logs. Timberland owners can improve the quality of their timber by removing the low-quality trees and applying other known methods of stand improvement.

A detailed report of the study is planned for issuance at an early date.

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Table 1.--Average yield of lumber by species, log grade, and lumber grade.

WHITE ELM

| Log grade | Yield by lumber grade: Firsts and Seconds | Select and No. 1 Com. | No. 2 Com. | No.3 Com. | Basis: Logs | Net Volume |
|---|---|---|---|---|---|---|
| | Percent | Percent | Percent | Percent | Number | Board Feet |
| 1 | 29.5 | 35.6 | 20.2 | 14.7 | 28 | 8,792 |
| 2 | 9.7 | 38.7 | 31.4 | 20.2 | 136 | 17,089 |
| 3 | 2.6 | 23.2 | 40.2 | 34.0 | 152 | 12,180 |
| Mill run 1/ | 12.5 | 33.2 | 30.8 | 23.5 | 336 | 40,856 |

COTTONWOOD

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 31.4 | 38.0 | 19.2 | 11.4 | 78 | 23,179 |
| 2 | 7.6 | 44.1 | 28.3 | 20.0 | 198 | 27,451 |
| 3 | 2.8 | 31.8 | 32.4 | 33.0 | 172 | 12,692 |
| Mill run 1/ | 17.0 | 38.3 | 24.8 | 19.9 | 376 | 46,611 |

NORTHERN RED OAK

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 34.4 | 41.8 | 13.5 | 10.3 | 59 | 9,989 |
| 2 | 8.9 | 45.5 | 24.9 | 20.7 | 96 | 10,930 |
| 3 | 1.6 | 17.9 | 30.8 | 47.6 | 115 | 7,610 |
| Mill run 1/ | 9.2 | 33.2 | 26.0 | 31.6 | 211 | 18,543 |

ALL THREE SPECIES LISTED ABOVE

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 31.7 | 38.4 | 18.1 | 11.8 | 165 | 41,960 |
| 2 | 8.6 | 42.6 | 28.5 | 20.3 | 424 | 55,470 |
| 3 | 2.4 | 25.3 | 35.0 | 37.3 | 439 | 32,482 |
| Mill run 1/ | 13.9 | 35.4 | 27.3 | 23.4 | 923 | 106,010 |

1/Because of the low proportion of Grade 1 and Grade 2 logs studied, it was necessary to include a few extra logs of these grades in order to strengthen the figures on their yield of lumber. These extra logs were not included in the "mill run" figures. Some white elm logs were included in the mill-run figures that were not shown in the individual log-grade figures.

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STATION NOTES
CENTRAL STATES FOREST EXPERIMENT STATION
COLUMBUS 15, OHIO

No. 142 March 1948

# A VOLUME TABLE FOR BLACK WALNUT TREES IN NATURAL STANDS IN IOWA

| Diameter breast high outside bark (Inches) | Volume (Doyle Rule) by merchantable height in 16-foot logs | | | | | | Average top diameter utilized (Inches) | Basis: number of trees |
|---|---|---|---|---|---|---|---|---|
| | 1/2 | 1 | 1-1/2 | 2 | 2-1/2 | 3 | | |
| | Board feet | Board feet | Board feet | Board feet | Board feet | Board feet | | |
| 15 | 58 | 79 | 93 | 107 | --- | --- | 11.5 | 1 |
| 16 | 64 | 94 | 117 | 134 | 154 | --- | 11.8 | 6 |
| 17 | 70 | 110 | 141 | 164 | 187 | --- | 12.2 | 8 |
| 18 | 78 | 127 | 164 | 194 | 220 | --- | 12.7 | 20 |
| 19 | 84 | 143 | 188 | 223 | 252 | --- | 13.1 | 20 |
| 20 | 92 | 161 | 212 | 254 | 287 | --- | 13.7 | 17 |
| 21 | 100 | 178 | 238 | 287 | 321 | 355 | 14.1 | 25 |
| 22 | 108 | 198 | 267 | 319 | 357 | 392 | 14.4 | 21 |
| 23 | 118 | 217 | 294 | 353 | 394 | 428 | 14.7 | 12 |
| 24 | 130 | 240 | 322 | 388 | 430 | 467 | 14.8 | 9 |
| 25 | 143 | 262 | 354 | 422 | 470 | 508 | 14.8 | 5 |
| 26 | 157 | 287 | 387 | 459 | 508 | 550 | 14.9 | 2 |
| 27 | 173 | 313 | 420 | 498 | 553 | 594 | 14.9 | 7 |
| 28 | 190 | 343 | 458 | 538 | 597 | 639 | 14.9 | 3 |
| 29 | 211 | 376 | 499 | 582 | 644 | 688 | 14.9 | 2 |
| 30 | 238 | 412 | 548 | 628 | 697 | 743 | 14.9 | --- |
| 31 | 265 | 457 | 601 | 683 | 754 | 801 | 14.9 | --- |
| 32 | 297 | 504 | 660 | 742 | 818 | --- | 15.0 | 2 |
| Basis (number) | 5 | 37 | 63 | 35 | 13 | 7 | --- | 160 |

This table is based on measurements taken on 160 single-stemmed black walnut (Juglans nigra L.) trees in the Iowa River bottoms of Tama County and in Clayton County, Iowa. The trees were felled in commercial cuttings and were utilized to a variable top diameter. Log lengths varied from 4 to 18 feet. Approximately 59 percent of the logs were 4 to 8 feet long, 22 percent were 9 to 10 feet, and 19 percent were 11 to 18 feet. Only one log exceeded 16 feet in length.

The measurements were made in 1945 by personnel of the Timber Production War Project and the Department of Forestry, Iowa State College. The table was prepared at the Central States Forest Experiment Station, Columbus, Ohio, using Girard's form-class taper method. Average taper and volume were computed in terms of eight-foot sections. Table values are 2.5 percent high in the aggregate. Trees forking above breast height and with merchantable material in more than one stem have 8.7 percent more volume than shown in the table.

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Station Note
No. 41

April 1, 1942

# NUTRITION OF ~~BLACK LOCUST IN FERTILIZED FIELD~~ PLANTINGS[1/]

By William Hawke Cummings, Assistant Silviculturist

Beginning in 1935, an investigation has been made on application of complete fertilizer at time of planting as a method for improving establishment of black locust on soils of low fertility in old fields and on spoil banks in the Central States region. The center-hole method of mattock planting was used, the spacing was 4 by 4 feet, and the fertilizer was mixed with the soil in the bottom of the planting hole before the tree was set. In one part of the investigation trees were planted on north-slope and corresponding south-slope sites; in another, use was made of 27 mixes of fertilizer with nitrogen, phosphorus, and potassium each varied at three levels, of which one series of aliquots was supplemented with crushed dolomitic limestone and another with pulverized peat; in another, five different levels of fertilizer application were tested. Since in general early survival was not affected by fertilizer applications, in assessing the effect of fertilizer early height increment was used as the single index of success of establishment.

In each experiment, marked response to fertilizing was evident in height growth through the first 2 years in the field. In one series of test plantings, for example, 2-year height growth of fertilized trees averaged 3.0 feet in comparison with 1.3 feet for untreated trees, and the corresponding values for the third year were 3.0 feet and 2.0 feet. Continued superiority in rate of development of fertilized trees after the initial 2-year period is ascribed largely to their better establishment. The results of applying complete fertilizer with each nutrient varied at three levels indicated the desirability of low nitrogen, high phosphorus, and low potassium levels. It could not be concluded that dolomite was a better supplement for fertilizer than peat. Increasing the quantity of fertilizer applied to small seedlings generally effected greater response; however, there was evidence of diminishing returns in the first 2 years' height growth from increased rates of fertilizing.

Leaf analysis was tested as a method for diagnosing nutrition. The results, notably for phosphorus, indicated that the technique of foliage diagnosis employed failed to assess the nutrition of black locust in the test plantings. A study was made of the nutrient content of the woody tops of black locust trees differentially fertilized at time of planting and not fertilized and displaying differences in development that were ascribed to the differences in fertilizer treatment. Markedly and consistently greater

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1/ This STATION NOTE summarizes an article which will ~~appear in the Journal of Agricultural Research, U.S.D.A.~~ be published soon. This mimeographed abstract has been prepared in response to requests for information regarding the results of this investigation.

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quantities of dry matter, phosphorus, potassium, and crude ash were found in the trees of each successively higher level of nutrition. A study was made, also, of the comparative height, root extent, top and root weights, and nutrient concentration of fertilized and untreated trees that had had one growing season in the field. Top weight averaged 4 grams for untreated trees but 13 grams for fertilized trees, and root weight averaged 7 grams for untreated trees but 20 grams for fertilized trees. Better nutrition of fertilized trees was not reflected by higher concentration of nutrients. The fertilized trees' advantage in nutrients contained in the woody top and roots approximated on the average 40 percent of the nitrogen, 3 percent of the phosphorus, and 20 percent of the potassium supplied in a 20-gram application of 4-12-4 fertilizer.

Analytic data on concentrations of nitrogen, phosphorus, and potassium in foliage and woody top material of black locust obtained in this study and derived from published reports by other investigators are summarized.

The results obtained indicate that in planting black locust on soils such as those of the experimental sites it is desirable to use in each planting spot fertilizer supplying about 1/2 gram of N, 1 or 2 grams of $P_2O_5$, and 1/2 gram of $K_2O$. Application at this rate in spots spaced 6 by 6 feet represents treatment of 1 acre of soil for each 144 acres planted, and is obviously feasible economically.

For primary plantings on abandoned land of low fertility otherwise suited for black locust, use of this species with application of fertilizer merits consideration. Through application of fertilizers that stimulate crown and root development the protective cover and soil-binding effects of black locust may be attained more rapidly.

U. S. Department of Agriculture - Forest Service
CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

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Station Note
No. 40.

August 1, 1941.

# OBJECTIVES IN FARM WOODS MANAGEMENT IN THE CENTRAL HARDWOOD REGION 1/

By J. Alfred Hall, Director

Farm woods of the central hardwood region vary widely as to size and as to proportion of total farm area. On good Corn Belt land the woodland area within a county rarely averages more than 10 or 12 acres per 120-acre farm, but south of the glacial boundary the average rises in some counties to 30 or 40 acres per 80-acre farm. In many Corn Belt counties gross woodland area amounts to less than 5 percent; in many hill counties, it exceeds 50 percent. To focus this discussion, I have roughly estimated the average woods area on farms in different parts of the region, as follows:

(1) Eastern Corn Belt, 10 - 12 percent.
(2) Western Corn Belt (Prairie), 0 - 10 percent.
(3) Old Glaciation (Illinoian), 10 - 20 percent.
(4) Ohio Valley, better rough lands, 15 - 25 percent.
(5) Ozarks, rougher hill country, 25 - 75 percent.

Composition and yield capacity vary just as widely, according to climate, site characteristics, and past treatment. Eastern Corn Belt woods contain good beech-maple stands and, where better drained, contain also oak-hickory stands, both good and poor. Toward the west, the Corn Belt has cottonwood, elm, ash, silver maple, and other species on the flood plains, and oak-hickory as the prevailing type on the uplands. The older glaciated areas, the soils of which are leached and often poorly drained, vary from poor pin oak or post oak flats to good beech-maple-poplar sites on rougher terrain. The better rough lands support stands varying from thin oak-hickory to excellent mixed hardwoods. The Ozark and Cumberland regions bear pine and oak-pine mixtures, also some fine stands of mixed hardwoods.

Any classification of farm woods as to either area or composition must be rough, until we have well-prepared geographic and cover-type maps. Even then, since the pattern is so complex, it will be impracticable to lay down fixed rules for farm woods management.

In preparing to set up objectives in management for any farm woodland, we must deal first with the following question:

(1) What is the general economy of the immediate territory?

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1/ Published in The Ames Forester, Vol. XXIX, pp. 31 - 34, 1941.

Certainly, farm woods will not play the same role in a rich corn belt county as in a rough hill county. In the first case, management is likely to be designed only to supply wood products needed for the farm. In the second, farming as such is likely to be only for subsistence, the major portion of the potential income being offered by the woods.

Corollary to the above is this question:

(2) What are the sustained-yield possibilities within a reasonable working circle?

In this regard also, there is a vast difference between areas. For example, a typical Corn Belt county of 300,000 acres has 30,000 acres of woods. At the rate of 200 board feet per acre per year, the county would produce 6 million feet of lumber annually, enough to run a good mill and supply the wood products necessary to the farm economy and local market. Not improbably, small quantities of specialty lumber such as black walnut or cherry could be produced and marketed. In a typical hill county of the same size but with 40 percent woodland, there are 120,000 acres of woods. Even at the low rate of 100 board feet per acre, these woods would yield 12 million feet of lumber per year. The wood requirements of farms, because of the much lower acreage of agricultural land, are much smaller in the hill country than in the Corn Belt, and the quantity of marketable products correspondingly much greater.

The possibility of profit from farm forestry depends on the market; and, conversely, market and primary and secondary manufacturing facilities have depended and will depend upon the volume and quality of wood available.

Discussion of sustained-yield possibilities leads to consideration of existing forest resources. We next ask ourselves, therefore:

(3) What is the general condition of the woods as regards growing stock and merchantable volume, and what are the possibilities for profitable woods management?

Particularly in the Corn Belt, the bulk of the woods are poorly stocked, overburdened with decadent, cull, and defective stuff, overcut, and overgrazed. Clearly, their rehabilitation will require time, good judgment, and in many cases cultural treatment. In the region as a whole, only a very small part of the total farm woodland area is in productive condition. Most of it cannot be brought into production without considerable investment of time and money and brains.

In this region money profit is not usually a primary motive in woods management, but in general the woods can and ought to contribute a considerable share of farm income in the form of materials to be used on the farm--lumber, posts, and fuel.

Where management for production of marketable logs and specialty woods is undertaken on the basis of very small wooded tracts forming a low percentage of total land area, it perhaps ought to be organized cooperatively. All the woods in a county, if pooled under a single management, might support a skilled manager and a primary manufacturing plant capable of turning out high-grade hardwood lumber. Commercial management by individual owners prevailingly results in a chaotic market and small opportunity to bargain, and thus offers little profit. In the hills, greater acreages and more compact units make cooperative management for market production more feasible than in the Corn Belt, where the wide distribution of production tends to prevent establishment of secondary manufacturing plants.

Another important consideration is the farm owner's will to practice forestry. With regard to objectives for any given locality, therefore, we ask:

(4) Is a tradition of forest economy present?

Most of the Midwest, we must agree, has little or no such tradition. Yet there are "cultural islands" where good woods practice goes hand in hand with good management of cropland. In such localities, encouragement and further refinement of management could develop very fine examples of profitable forestry and afford convincing proof to more backward communities that farm forestry pays.

In parts of the Corn Belt, one misses entirely any will toward woods management. Where soils are deep and rich, the conscious choice has always been to clear and plow. I doubt the wisdom of much effort toward bringing about a reversal of this tendency, even though it can be shown that a woodland is typically a profitable part of a Corn Belt farm. Choices as to future land-use policies are going to be made on the clear basis of the desires, not merely the needs, of farm owners. Foresters' efforts can be more profitably expended where growing stock still exists and where some of the people have at least a background of woods economy.

There is, however, some territory where, although forests never were plentiful, farmers do want and need woods, for production and for shelter. We ask, therefore:

(5) If planting is needed, what should be planted?

Shall we plant for market or only for farm needs? The existing examples of successful planting for commercial production are generally confined to specialty woods such as black walnut. For farm posts, fuel, and lumber, such species as black locust, hardy catalpa, eastern red cedar, cottonwood, and the native pines are suggested; for shelter, conifers are preferable. Here again, choice depends on whether the objective is a permanent woods, reproducing itself, or single crops the harvesting of which will be followed by repeated plantings.

I trust I have succeeded in showing, briefly and roughly, that hard and fast rules for managing the farm woods cannot be formulated. What plan of management should be chosen depends in every case on the requirements and conditions of the land, of the community, and of the region, and on the individual owner's desires and circumstances. Each farm is a problem in itself. The general objective, we may be sure, is to produce wood for use and profit or to grow trees for shelter--not to grow trees just for the fun of it. Only a judicious combination of technical forestry, economics, and a large share of common sense can make productive and profitable management of farm woods a reality.

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# PERFORMANCE OF HYBRID POPLAR CUTTINGS IN THE FOREST SERVICE NURSERY, VALLONIA, INDIANA

By

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Cuttings representing twenty-five hybrid poplar clones, furnished by the Northeastern Forest Experiment Station, were planted in the Forest Service nursery at Vallonia, Indiana, early in April, 1938. This was in accordance with the plan of that Station to evaluate the clones growing under different climatic conditions throughout the country. The cuttings, uniformly twelve inches in height and varying in diameter, were received and stratified at the nursery in the fall of 1937.

## NURSERY PLOT ESTABLISHMENT

The plantings were made in a nursery unit in randomized plots to permit scrutiny of quantitative differences in behavior. The planting stock of each clone was divided into two lots of equal numbers, making a total of fifty lots, thus affording two replications for each clone. Every lot was assigned a random position in the unit, Figure 1. The individuals within a replication were planted approximately six inches apart in rows four feet apart. Each lot was adequately labeled for subsequent identification.

The cuttings, with a planted height of four inches, were set eight inches in the soil. The diameter of each cutting, at a point three inches above the ground, was recorded soon after planting.

Figure 1. Randomized plots of hybrid poplars at the Vallonia Nursery, Block IV, Sec. IV, Unit 12.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Row 1 | OP - 39 | OP - 6 | OP - 43 | OP - 47 | OP - 32 | OP - 2 | OP - 42 |
| Row 2 | OP - 6 | OP - 21 | OP - 46 | OP - 56 | OP - 45 | OP - 21 | OP - 29 |
| Row 3 | OP - 23 | OP - 48 | OP - 52 | OP - 4 | OP - 50 | OP - 3 | OP - 29 |
| Row 4 | OP - 37 | OP - 4 | OP - 50 | OP - 47 | OP - 23 | OP - 41 | OP - 52 |
| Row 5 | OP - 28 | OP - 12 | OP - 32 | OP - 2 | OP - 33 | OP - 48 | OP - 54 |
| Row 6 | OP - 54 | OP - 45 | OP - 3 | OP - 42 | OP - 56 | OP - 46 | OP - 39 |
| Row 7 | OP - 9 | OP - 43 | OP - 37 | OP - 33 | OP - 28 | OP - 12 | OP - 41 |
| Row 8 | OP - 9 | | | | | | |

## CLIMATIC CONDITIONS

Weather records kept by the Vallonia Nursery furnish accurate data on the general climate of the planting site. The climatological data for the duration of the period over which observations on the cuttings have been made are summarized in Table 1. Quite adequate rainfall was well distributed throughout the growing season, and it will be noted that the winter temperatures were unusually mild for this region.

## SOIL

The soil at the Vallonia Nursery is a deep alluvial deposit, classified as a Princeton sandy loam, part of a terminal moraine of an early glaciation. It is very well drained, well aerated and well oxidized; low in essential mineral elements because of excessive leaching; and low in organic material because of previous cultivation.

## TREATMENT AND CARE

Maximum care was given the cuttings during the growing season. The unit, in which the planting was made, was kept weed-free by cultivation. The rows were cultivated once a week during the month of May, once every two weeks during June and July, and once in August. After that time, the cuttings had attained such a size, and the period of establishment of the weeds had so far progressed that no weeds developed in the unit.

Table 1. Climatological Data - Vallonia, Indiana 1938 - 1939

| Month | Rainfall in Inches | Average Daily Maximum Temp. ° Fahrenheit | Average Daily Minimum Temp. ° Fahrenheit |
|---|---|---|---|
| April '38 | 1.17 | 68.5 | 43.3 |
| May '38 | 4.35 | 74.7 | 50.9 |
| June '38 | 4.10 | 74.0 | 57.5 |
| July '38 | 6.89 | 86.0 | 62.9 |
| August '38 | 2.00 | 86.9 | 62.8 |
| September '38 | 1.75 | 81.8 | 55.8 |
| October '38 | .66 | 74.6 | 38.9 |
| November '38 | 4.65 | 58.2 | 31.2 |
| December '38 | 1.56 | 48.0 | 23.7 |
| January '39 | 5.12 | 48.2 | 27.6 |
| February '39 | 4.75 | 46.8 | 20.7 |
| March '39 | 6.91 | 56.4 | 31.9 |

No irrigation or watering of the cuttings was necessary due to the adequate precipitation during the major part of the growing season.

Insect injury became evident on the foliage of some of the clones early in the summer. This became severe, and three separate applications of lead arsenate spray were made but with only temporary effect in each case. Apparently the many simultaneous broods and the presence of different instars of the defoliating insect, which was identified as the Cottonwood Leaf-bettle (Lina scripta Fabr.), accounted for the recurrence of the beetles after the toxic effects of the arsenate spray had diminished. A later application of a spray mixture of lead arsenate and nicotine sulphate was effective in checking the insect damage to a considerable extent.

## OBSERVATIONS AND DATA

A field examination of the clones was made on September 15, 1938, but as the growing season had not yet ended, no quantitative measurements were made at this time. This examination disclosed that four clones had been affected by a leaf rust (Melampsora sp.). The rust was evident upon both replications of the clones affected and was apparently not as severe upon the clone OP-33 as it was upon the other three infected clones: OP-32, OP-37, and OP-39.

The extent of beetle injury varied somewhat among the different clones, but was comparatively the same upon the two replicates of an individual clone. The clones, which appeared to be damaged to such an extent that the injury would be a serious factor in the establishment of the cuttings if unprotected by application of sprays, were noted and are indicated in Table 2.

Consistency in leaf shape and size was evidenced within the replications of a clone, and a wide variation in these characters was noted between the clones of the entire series. Both replications of the individual clones were consistent in all the exterior evidences of growth, size, form, branchiness, etc.

Measurements were taken on the individual cuttings on November 8, 1938, after the growth had ceased. Diameters were measured at a point three inches above the ground in order to be comparable with the diameters taken at the time of planting. Total height was measured to the nearest half-foot. A total height measurement is assumed to be a valid expression of height increment because of the uniformity of the planted heights of the cuttings. The mean diameter increment and the mean height increment for each replication of every clone were computed from these data. For purposes of analysis these means were kept separate, but for general comparison, the values for the replicates of each clone were weighted and averaged to give a single value of height and diameter increment for each clone. These latter data appear in Table 2. The height value was changed from half-foot units to foot in order to give a more readily applied basis of comparison.

Table 2. Behavior of hybrid poplar cuttings in the Vallonia Nursery

| Clone No. | Number of Cuttings Planted | Survival | | | Rust on Leaves Sept. 15 | Branchiness in Number of Branches | Mean Diameter Increment Inches/10 | Mean Height in Feet | Heavy Insect Attack |
|---|---|---|---|---|---|---|---|---|---|
| | | Each replication | | Per Cent | | | | | |
| | | 1 | 2 | | | | | | |
| OP - 2 | 100 | 49 | 47 | 96 | | 57 | 4.3 | 7.8 | |
| OP - 3 | 100 | 49 | 46 | 95 | | 28 | 3.4 | 8.2 | |
| OP - 4 | 101 | 49 | 49 | 98 | | 20 | 3.0 | 7.2 | * |
| OP - 6 | 100 | 50 | 50 | 100 | | 17 | 3.3 | 8.6 | |
| OP - 9 | 100 | 50 | 50 | 100 | | 68 | 2.6 | 6.6 | * |
| OP - 12 | 100 | 44 | 50 | 94 | | 18 | 2.1 | 7.0 | * |
| OP - 21 | 100 | 38 | 39 | 77 | | 24 | 3.4 | 8.0 | |
| OP - 23 | 95 | 42 | 34 | 80 | | 8 | 1.9 | 6.6 | |
| OP - 28 | 100 | 40 | 45 | 85 | | 17 | 2.4 | 6.5 | * |
| OP - 29 | 100 | 50 | 50 | 100 | | 5 | 3.2 | 8.3 | |
| OP - 32 | 100 | 29 | 30 | 59 | * | 14 | 3.1 | 6.0 | * |
| OP - 33 | 100 | 36 | 44 | 80 | * | 9 | 2.0 | 5.9 | |
| OP - 37 | 100 | 42 | 41 | 83 | * | 25 | 2.8 | 5.4 | * |
| OP - 39 | 100 | 48 | 46 | 94 | * | 25 | 2.0 | 5.7 | * |
| OP - 41 | 100 | 49 | 48 | 97 | | 15 | 2.2 | 7.6 | |
| OP - 42 | 100 | 50 | 49 | 99 | | 1 | 2.8 | 7.4 | |
| OP - 43 | 100 | 50 | 47 | 97 | | 2 | 2.3 | 6.6 | * |
| OP - 45 | 100 | 50 | 50 | 100 | | 5 | 2.4 | 7.5 | * |
| OP - 46 | 100 | 50 | 48 | 98 | | 10 | 2.0 | 7.3 | * |
| OP - 47 | 100 | 49 | 42 | 91 | | 10 | 2.9 | 6.8 | * |
| OP - 48 | 100 | 46 | 50 | 96 | | 6 | 2.1 | 6.7 | |
| OP - 50 | 100 | 47 | 44 | 91 | | 3 | 2.4 | 7.3 | * |
| OP - 52 | 100 | 49 | 46 | 95 | | 5 | 2.3 | 6.4 | |
| OP - 54 | 100 | 49 | 50 | 99 | | 29 | 2.8 | 7.3 | * |
| OP - 56 | 99 | 44 | 39 | 83 | | 27 | 2.7 | 6.6 | |

Individual clones varied from one another in the number of branches produced, but replications of individual clones were apparently consistent in this respect. An attempt was made to give a comparative figure for the characteristic of branchiness of the clones. A tree which was considered to be average was selected by inspection in each clone. The number of branches on this "average" tree were then counted and this number used as a basis for evaluating the clones as to branchiness. This value is tabulated in Table 2. The method is not a precise one, but it does convey the significant range of the variation of the clones in respect to the number of branches produced.

Cuttings were made in the late fall of most of the individuals in each clone. These cuttings were bundled by clones, and stratified in sand. A few representatives of every clone were left standing in the nursery unit over the winter. Examination of these specimens in the spring indicated that no dying back due to winter conditions had occured in any of the clones.

The cuttings were taken from stratification in March 1939 and planted in experimental plots. Early observations upon these field planted cuttings indicate that the clones vary in the time of bud development or breaking of dormancy. The clones were evaluated as to the extent to which they had broken dormancy at the time of observation, April 21, 1939, and these data are shown in Table 3. Each of the four main groups of this table is further subdivided into two classes separated by a space. The first class in each group is the one which is the further advanced.

Table 3. Extent to which clones had broken dormancy by the end of April. Observations on field planted cuttings.

| Clones in which leaves were well developed | Clones in which leaves were unfolding | Clones in which buds were breaking | Clones in which buds were swollen |
|---|---|---|---|
| OP - 41 | OP - 28 | OP - 23 | OP - 9 |
| OP - 45 | OP - 29 | OP - 42 | OP - 37 |
| OP - 46 | OP - 33 | | |
| OP - 50 | OP - 54 | OP - 21 | OP - 3 |
| | OP - 56 | OP - 12 | |
| OP - 4 | | | |
| OP - 43 | OP - 6 | | |
| OP - 52 | OP - 32 | | |
| | OP - 39 | | |
| | OP - 48 | | |
| | OP - 2 | | |
| | OP - 47 | | |

## ANALYSIS OF GROWTH DATA

The mean diameter and mean height increments for each replicate of every clone were individually subjected to an Analysis of Variance. This inspection showed a non-significant variation in each case. The mean diameter increment showed nearly as great a range between replicates of a single clone as it did between the clones, consequently no further examination of these data was considered necessary.

The means of the heights for clones show a range of from 10.9 to 17.3 (half-foot units). The clones were arranged according to their mean height and the significance of variation of the means, using the lowest value (10.9) as the basis, was computed.

These calculations resolved the clones into three distinct groups; those whose mean height does not vary significantly from the mean height of the shortest clone, those whose mean height does vary significantly, and those whose mean height varies highly significantly with the mean height of the shortest clone. The results obtained by this comparison are set forth in Table 4.

In examining Table 4, it is interesting to note that the four clones with the lowest mean height values are those which were affected by the Melampsora rust.

The cuttings were grouped into their respective planted diameter classes irrespective of clones, and the mean height and percent mortality were computed for each diameter class. These data are contained in Table 5. There is apparently no great significant difference either in height growth or mortality for the individual planted diameter classes. The data in Table 5, however, do indicate that height increment does not show a large increase with an increase in the planted diameter of the cutting within the limits of the data gathered in this instance.

Table 4. Comparison of the mean heights of clones with the lowest mean height, that of clone OP-37.

| Clones whose mean height varies non-significantly with the lowest mean height (10.9) | | Clones whose mean height varies significantly with the lowest mean height | | Clones whose mean height varies highly significantly with the lowest mean height | |
|---|---|---|---|---|---|
| Clone No. | Mean height in ½-ft. units | Clone No. | Mean height in ½-ft., units | Clone No. | Mean height in ½-ft. units |
| OP - 37 | 10.9 | OP - 4 | 14.4 | OP - 21 | 16.0 |
| OP - 39 | 11.4 | OP - 46 | 14.6 | OP - 3 | 16.4 |
| OP - 33 | 11.8 | OP - 50 | 14.6 | OP - 29 | 16.6 |
| OP - 32 | 12.0 | OP - 54 | 14.6 | OP - 6 | 17.3 |
| OP - 52 | 12.7 | OP - 42 | 14.8 | | |
| OP - 28 | 13.0 | OP - 45 | 15.0 | | |
| OP - 43 | 13.1 | OP - 41 | 15.1 | | |
| OP - 56 | 13.2 | OP - 2 | 15.6 | | |
| OP - 23 | 13.3 | | | | |
| OP - 9 | 13.3 | | | | |
| OP - 48 | 13.4 | | | | |
| OP - 47 | 13.6 | | | | |
| OP - 12 | 13.9 | | | | |

Table 5. Behavior of cuttings according to diameter class.

| Diameter Class in Tenth/inches | No. Planted | No. Surviving | Total Height | Mean Height | No. Dead | Percent Mortality |
|---|---|---|---|---|---|---|
| .1 | 1 | | | | 1 | 100 |
| .2 | 665 | 561 | 7,724 | 13.8 | 104 | 16 |
| .3 | 1,354 | 1,281 | 18,268 | 14.3 | 73 | 5 |
| .4 | 386 | 371 | 5,319 | 14.3 | 15 | 4 |
| .5 | 68 | 60 | 812 | 13.5 | 8 | 12 |
| .6 | 16 | 16 | 221 | 13.8 | 0 | 0 |
| .7 | 4 | 4 | 50 | 12.5 | 0 | 0 |

## SUMMARY

Cuttings of twenty-five clones of hybrid poplar were set out in the Forest Service Nursery at Vallonia, Indiana, in the spring of 1938. Observations were made on the behavior of the cuttings in the nursery at the end of the first growing season. Cuttings were made from this planting and stratified over winter. These cuttings were planted under field conditions in the spring of 1939.

The clones sorted out into a definite order in respect to increment and general behavior during the first growing season.

Differential resistance of the clones to insect and fungous attack was manifested during the growing season in the nursery.

No correlation was found, within the scope of the data, between planted diameter of the cuttings and increment.

There was no winter mortality or dying back due to winter conditions on the individuals left in the bed at the Vallonia nursery during the winter of 1938 - 1939.

There is a noticeable variation in the time at which dormancy is broken by the various clones.

Plantings under various field conditions have been made with cuttings of each clone. Data as to the differential behavior of the clones under the several field conditions will be gathered, and an evaluation of the suitability of the various clones for field planting can be made on the basis of these later data.

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# TREE DEFECTS AND STAND CONDITIONS ON THE HACKER CREEK EXPERIMENTAL AREA MORGAN-MONROE STATE FOREST INDIANA*

By

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and
John G. Kuenzel, Assistant Silviculturist

Studies have been made on several of the recently acquired State and Federal forests of the central hardwood region to determine the character of the stands and the extent and principal causes of tree defect. Knowledge of these factors is needed in formulating silvicultural recommendations for specific areas and in deciding upon region-wide cultural policies. Such a study was made in 1937 on the 160-acre Hacker Creek Experimental Area, on the Morgan-Monroe State Forest, in southern Indiana.

This experimental area lies just south of the limit of glaciation. It presents a complexity of site conditions graduating from the narrow, damp flood plains of Hacker Creek to exposed south slopes and ridge tops. Logging operations during the period 1890-1900 and cuttings at irregular intervals thereafter removed from it all merchantable trees suitable for lumber and ties. The flood plains and ridge tops were under cultivation as late as 1925, and are now occupied by native weeds, grasses, and shrubs.

A randomized 5-percent strip cruise was made. Every tenth tree more than 2.5 inches in d.b.h. on the strips was examined for defect, regardless of species or condition; this gave a 0.5-percent random sample of the defect in the stand. A count of the reproduction was made on a 100-foot-square quadrat for each chain of line cruised.

## Stand Conditions

The cruise revealed stand conditions as follows:

1. The stand contains 170 trees 2.5 inches and more in d.b.h. per acre, averaging 6.5 inches in d.b.h., 40.6 feet in height, and 37 years in age and having, on the average, an annual diameter growth per tree of 0.2 inch.

2. The white oak-black oak-red oak type occupies 50 percent of the area.

3. Approximately 20 percent of the area is grassland.

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* The field work of this study was done in cooperation with the Indiana Department of Conservation, Division of Forestry, and with C.C.C. Camp S-52, Martinsville, Indiana.

4. Reproduction less than 2.5 inches in diameter averaged 972 stems per acre. About 50 percent of the reproduction was sassafras, 20 percent oaks and hickories, and the remainder aspen, maple, and other hardwoods.

5. Approximately 80 percent of the reproduction was less than 0.6 inch in diameter and only 4 percent was more than 1.6 inches in diameter.

A summary of the condition of the overstory by species group and diameter class, and of its growth, is given in table 1.

Table 1.--Summary of stand conditions and growth

| Species group[1] and diameter class[2] (inches) | Av. trees per acre | Av. height | Av. d.b.h. | Av. age | Av. annual diameter increment |
|---|---|---|---|---|---|
| | Number | Feet | Inches | Years | Inches |
| White oaks | | | | | |
| Saplings | 16 | 25 | 3.1 | 25 | 0.12 |
| Small poles | 20 | 39 | 6.0 | 31 | 0.22 |
| Large poles | 10 | 48 | 9.0 | 50 | 0.20 |
| Merchantable | 10 | 49 | 11.2 | 50 | 0.18 |
| Black oaks | | | | | |
| Saplings | 12 | 28 | 3.0 | 24 | 0.12 |
| Small poles | 16 | 39 | 5.4 | 31 | 0.20 |
| Large poles | 8 | 54 | 8.5 | 47 | 0.22 |
| Merchantable | 9 | 58 | 11.8 | 42 | 0.30 |
| Shagbark hickory | | | | | |
| Saplings | 5 | 25 | 3.1 | 28 | 0.12 |
| Small poles | 5 | 33 | 5.0 | 28 | 0.22 |
| Large poles | 1 | 62 | 8.3 | 52 | 0.14 |
| Merchantable | - | - | - | - | - |
| Other commercial species | | | | | |
| Saplings | 18 | 56 | 3.1 | 30 | 0.12 |
| Small poles | 24 | 40 | 4.8 | 30 | 0.18 |
| Large poles | 7 | 57 | 9.0 | 61 | 0.18 |
| Merchantable | 9 | 61 | 12.9 | 73 | 0.14 |

1/ White oaks = white oak and chestnut oak.
Black oaks = red oak, scarlet oak, and black oak.
Other commercial species = aspen, beech, black walnut, yellow poplar, pignut hickory, mockernut hickory, black gum, and maple.

2/ The breast-height diameter classification used here, that of Forest Service Region 9, is as follows: Saplings, 2.5-3.5 inches; small poles, 3.6-7.5 inches; large poles, 7.6-9.5 inches; and merchantable, more than 9.6 inches.

## Tree Defect

The tree-defect study was made to determine the types of defect present in the overstory trees, their relative frequency, and their relation to the volume of sound timber present on the area. Measurements were taken to determine the extent of decay or volume loss resulting from fire scars, branch stubs, insect tunnels, and miscellaneous defects.

Although the information obtained represents only a small part of the Morgan-Monroe Forest, this part may be considered a fair sample of the whole, since the entire forest has had a practically uniform history.

Fire Damage. Of the 107 overstory trees examined, 46 percent had fire scars; 35 percent of the scarred trees had open wounds and 65 percent had closed wounds. Every one of the fire-scarred trees contained some decay. A summary of fire scarring in the overstory is given in table 2.

Table 2.--Fire scarring, by species group and nature of scar

| Species group 1/ | Tree basis | Total trees with fire scars | Trees with open scars | Trees with closed scars |
|---|---|---|---|---|
| | Number | Percent | Percent | Percent |
| White oaks | 37 | 51.3 | 16.2 | 35.1 |
| Black oaks | 31 | 54.9 | 6.5 | 48.4 |
| Shagbark hickory | 11 | 9.0 | - | 9.0 |
| Other commercial species | 28 | 42.9 | 28.6 | 14.3 |
| All species | 107 | 45.8 | 15.0 | 30 8 |

1/ For composition of species groups, see table 1.

During the period 1898-1928, dates of the earliest and the most recent fires of which evidence was found, at least 24 separate fires had occurred. The evidence pointed to a definite cessation of fires after 1928, when organized protection was initiated.

Branch Stubs. Of the trees examined, 85 percent were found to have branch stubs, and when dissected about 55 percent showed decay associated with such stubs. No significant difference appeared among species in susceptibility to branch-stub decay.

Insect Injury. Half the trees examined had been injured by insects, and each of these trees, on the average, had two separate points of attack.

The insects found on the area and identified by the Bureau of Entomology and Plant Quarantine were of only three primary families. They were Cerambycidae (round-

headed borers), species Goes pulverulentus and G. pulcher; Cossidae (carpenter moths), species Prionoxystus macmurtei; and Tenebrionidae (darkling beetles), species Strongylium tenuicolle.

Volume Loss Percent. On the basis of 104 sample trees, 9.5 percent of the total volume was defective. Fire damage was responsible for 63 percent of the total defective volume. Insects were second in importance, with 11 percent; and decay entering through branch stubs accounted for 6 percent. The remaining 20 percent of the defective volume resulted from miscellaneous injuries.

The white oak and black oak groups showed the largest volume of defect, shagbark hickory the smallest.

The results of the study of defect are summarized in table 3.

Table 3.--Extent of defect, by species group and cause

| Species group | Tree basis | Volume of av. tree | Total volume | Defective volume, by cause | | | |
|---|---|---|---|---|---|---|---|
| | | | | Fire scar | Branch stub | Insects | Total 1/ |
| | Number | Cu.ft. | Cu.ft. | Percent | Percent | Percent | Percent |
| White oaks | 35 | 4.3 | 150.4 | 8.8 | 0.2 | 0.3 | 11.1 |
| Black oaks | 29 | 3.0 | 87.3 | 6.2 | 0.5 | 3.3 | 11.1 |
| Shagbark hickory | 12 | 1.1 | 13.2 | 0.0 | 0.1 | 0.1 | 5.3 |
| Other commercial species | 28 | 4.1 | 115.5 | 3.9 | 1.0 | 0.2 | 7.2 |
| All species | 104 | 3.2 | 366.4 | 6.0 | 0.5 | 0.9 | 9.5 |

1/ Including defects resulting not only from major causes but from butt rot, wind shake, frost crack, mechanical wounding, and other miscellaneous causes.

Visibility of Defects. Each sample tree was carefully examined before felling for evidence of defect, and volume loss associated with defects invisible before felling was recorded separately. The ratio of losses from the two types of defect was about 1:1. This indicates the difficulties encountered in marking upland hardwood stands for cultural operations and in determining cull deduction in stumpage sales.

## Discussion

With the exception of the large number of insect injuries, the findings in regard to defect were in line with those of defect studies in hardwood stands elsewhere in the Central States region. Although 93 percent of the trees had one or more defects, the total defective volume was not high (9.5 percent). This is explained in part by the low average age of the stand.

Approximately half the trees examined were found to have been injured by fire; all the fire-damaged trees were defective, and about two-thirds of the total volume loss from defect was traceable to fire injury. These facts very clearly indicate the need of adequate fire protection if stands such as that examined are to produce high-quality materials.

Analysis of the data showed that about half the trees had decay traceable to branch stubs, but only 0.5 percent of the total volume loss was attributed to this type of defect. The ratio of fire scars to branch stubs was about 1:1, but the percentage losses traceable to these two factors showed a ratio of approximately 11:1.

In frequency of occurrence insect injury ranked first among the causes of defect, but in volume loss percent it ranked second. The ratio of fire-scar losses to insect losses was about 6:1.

The remaining 2.1 percent volume loss was traceable to a number of causes such as butt rot transmitted from the parent stump, climatic injuries, and mechanical wounding.

Adequate fire protection would eliminate from future stands much of the defect that has resulted from fires in the existing stands. Silvicultural practices that improve growth rates and release suppressed trees would tend to reduce losses from infection through branch stubs and from insect attack. Sanitation cuttings should be made to remove defective, poorly formed, and otherwise undesirable trees from the stands. In any cultural operation, careful consideration should be given to the trees to be left on the area. The trees retained should be sound, well-formed individuals, numerous enough to ensure straight, clear form and natural pruning.

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November 1, 1939

# SOME EFFECTS OF RELEASE ON PLANTED SHORTLEAF PINE IN THE MISSOURI OZARKS

By

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and
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Planting in the recently established National Forests in the Missouri Ozarks has been, and apparently will continue to be, confined largely to the underplanting of stands of undesirable species with shortleaf pine. It is recognized that many of these plantations will have to be released if a satisfactory growth rate of the pine is to be maintained. An opportunity to obtain some preliminary information on the effects of various types and amounts of release on planted shortleaf pine was provided in connection with studies on methods of controlling sprouting. Data on the growth and mortality of planted pine on these sprouting study plots, taken at the end of the first growing season after release, are presented in this progress report.

## The Studies

The treatment of the overstory in these studies included three methods of killing the tops of the trees, applied at four intensities and at three different times of the year. Because of the difficulties encountered in finding a uniform area sufficiently large to accommodate all combinations of these three variants, it was necessary to divide the study and to use two similar areas. One of these areas is located in Howell County on the Willow Springs Ranger District and the other in Reynolds County on the Salem Ranger District. Both areas are gently rolling and supported fairly dense stands of blackjack oak saplings and poles.

On the Willow Springs Ranger District the study consisted of two replications of four methods of treatment (including the check) made at three seasons of the year, thus using a total of 24 tenth-acre plots. The four methods of treatment were: (1) cutting, the removal

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1/ John L. Arend and B. F. Seizert, Junior Foresters in CCC camps on the Mark Twain and Clark National Forests, assisted with the field work on these studies.

of all of the overstory trees, providing an immediate release; (2) notch-girdling, the killing of all of the trees by the removal of a ring of bark and sapwood, thus bringing about a gradual release during the first year; (3) peel-girdling, the gradual killing of all of the trees by the removal of a ring of bark without cutting into the wood, thus bringing about a gradual release during the first two or more years; and (4) check, no trees were killed and consequently no release was made. These treatments were made at three seasons of the year: (1) dormant season, in February before growth started; (2) early growing season, in May during the active growth period; and (3) late growing season, during August after the major part of the height growth had taken place.

The study on the Salem Ranger District consisted of three replications of three methods of treatment applied at four intensities during the dormant season. The methods of treatment (cut, notch-girdle and peel-girdle) were the same as those used in the Willow Springs study. The four intensities of release were: (1) 100 percent release, all of the trees in the overstory were treated; (2) 67 percent release, a sufficient number of the trees were treated so that the basal area[2/] of the untreated trees on each plot was one-third of the average basal area of the overstory trees on all of the plots; (3) 33 percent release, two-thirds of the average basal area was left untreated; and (4) no release, none of the trees was treated.

## Results

The average 1938 height growth of the 810 one-year shortleaf pine seedlings planted on the plots on the Willow Springs Ranger District in the spring of 1938, the year during which the treatments were made, is shown graphically, by methods and months of treatment, in Figure 1. Although ultimately all methods and months of treatment will result in a 100 percent release there was a great variation in the amounts and rates of effective release during the first growing season. Complete release accompanied removal of the overstory trees by cutting and was effective over periods of approximately eight, five and two months on the plots treated in February, May and August, respectively. Release brought about by notch and peel-girdling was gradual and was only about 60 and 10 percent effective, respectively, by the end of the growing season. There was, of course, no release on the check plots.

The height growth of the pine increased with an increase in the length of growing season after treatment for all methods of release. The trend was steep and regular for treatment made by cutting; was steep but irregular for releases made by notch-girdling; and, was nearly flat and statistically insignificant for releases made by peel-girdling and for the check plots.

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2/ There was a close correlation between the basal area and the crown area of the overstory trees used in this study.

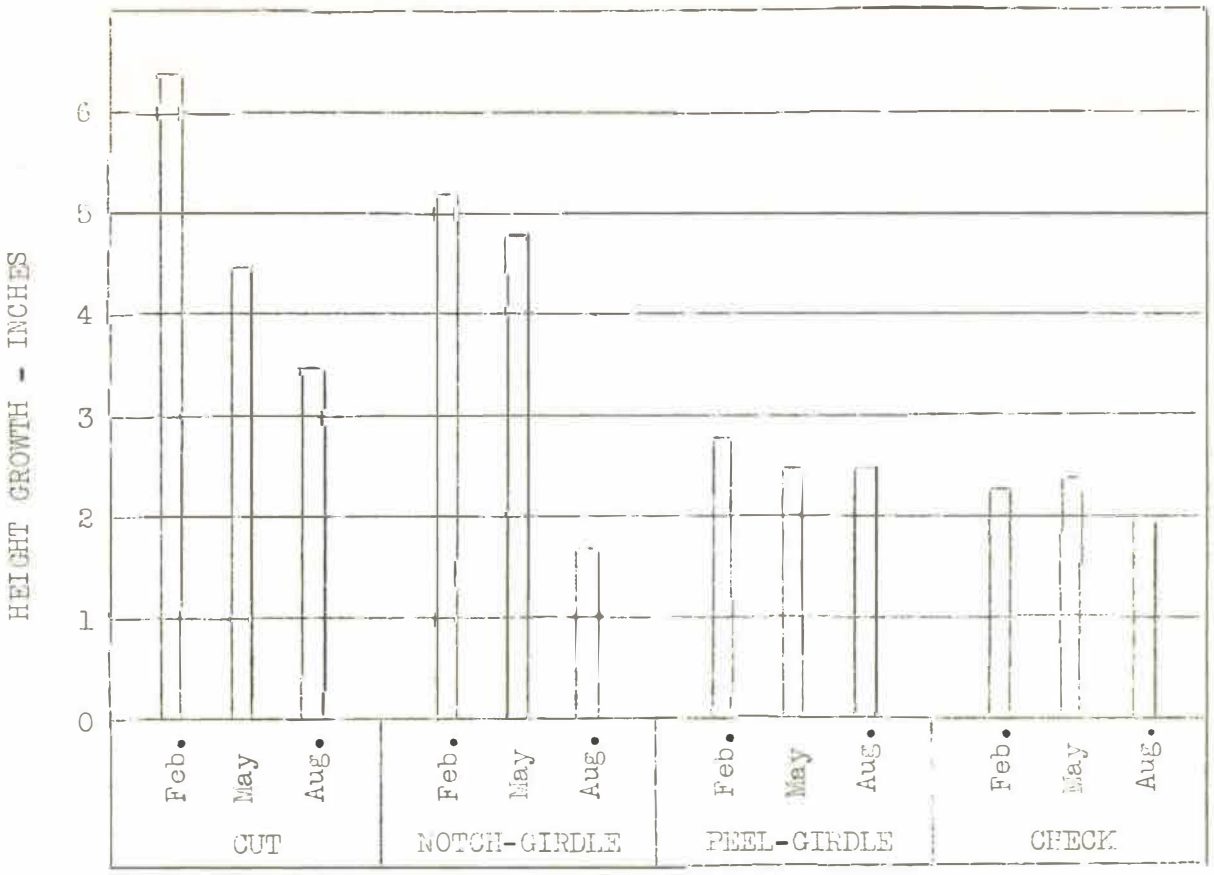


Figure 1,- The 1938 height growth of 1-0 shortleaf pine planted on the Willow Springs Ranger District in the spring of 1938 and released at intervals during the 1938 growing season.

The height growth of the pine released in February averaged 6.4 inches on plots released by cutting, 5.2 for notch-girdling, 2.8 for peel-girdling and 2.3 on the untreated plots. This varies directly with the amounts of release, which were approximately 100, 60, 10, and 0 percent, respectively, at the end of the first growing season. The growth rates of the pine released by cutting and notch-girdling in May (see Figure 1 again) were approximately equal, and were greater than the growth rates on the plots released by peel-girdling and on the check plots. As would be expected, because of the short length of the remaining growing period, the differences in the effects of treatments in August were not as pronounced as in the other two seasons. The only significant increase occurred on the plots released immediately and completely by cutting.

The mortality of the pine on the release plots averaged approximately 16 percent as compared to 10 percent on the check plots. Although this represents a 60 percent increase in mortality it is statistically insignificant, because of the inconsistencies in the direction and degrees of variation and the large variations between plots receiving the same treatment.

The plots on the Salem Ranger District were planted with 1-0 shortleaf pine in the fall of 1936. About one-half of these died prior to the spring of 1938, when this study was initiated. The average 1938 height growth of 560 of the surviving individuals, distributed over all 36 plots, is shown graphically, by methods and intensities of treatment, in Figure 2. For all methods of release the height growth of the pine increased with an increase in the amount of release. In each instance, treatment of the last one-third of the overstory resulted in a greater increase in the growth of the pine than did the treatment of either the first or the second one-third. The increase in growth on the treated plots over that on the untreated plots was significant only on those released 100 percent. Within each intensity of treatment, the variations in height growth of the pine between methods of release were not significant.

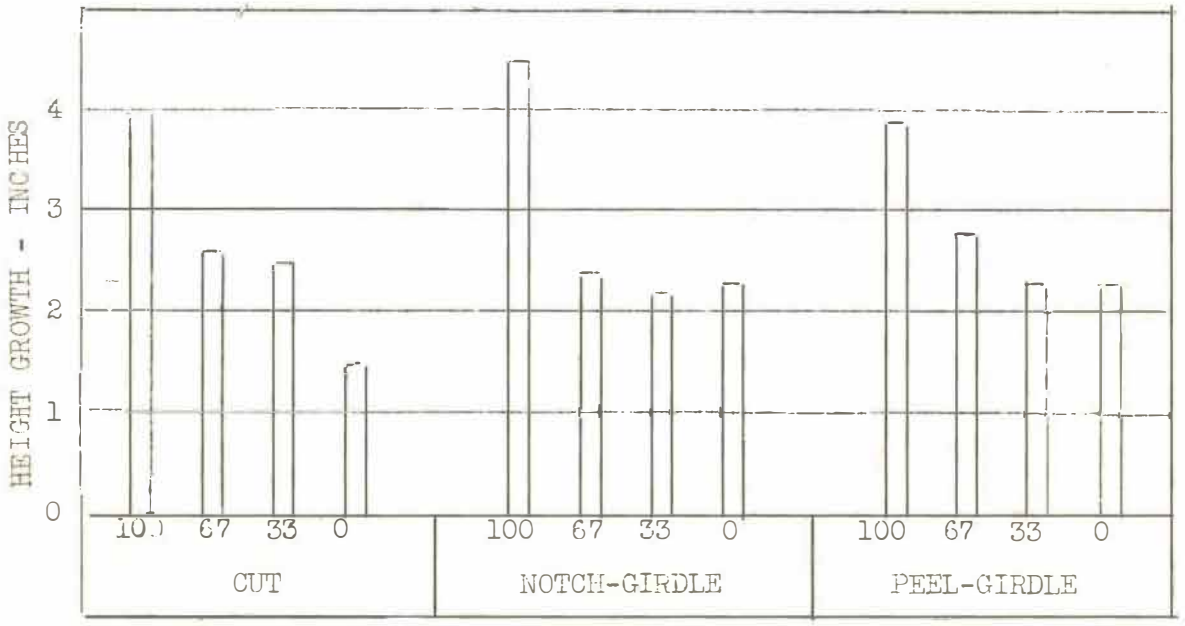


Figure 2.- 1938 height growth of 1-0 shortleaf pine planted on the Salem Ranger District in the fall of 1936 and released just prior to the 1938 growing season.

The average mortality of the pines on the released plots on the Salem area was approximately 15.5 percent as compared to 5 percent on unreleased plots. An unexpectedly high mortality of 88.5 percent on the plots released 100 percent by cutting was responsible for practically all of this increase and was the only treatment that gave a significant increase in mortality.

## Discussion

The above results are based on data taken at the end of the first growing season after release and consequently may not be true indications of the ultimate effects of the different types of releases on the growth rate and mortality of planted pine. This is particularly true of those differences that have resulted from the two methods of girdling and the three months of treatment. During each succeeding growing season the differences in the densities of the overstory on those plots on which all trees were treated will decrease until each has been released 100 percent. Subsequent differences in the pine on these plots will then be due to difference in rate of release rather than the amount of release.

As was mentioned above, the pine on the Willow Springs area was planted in the spring of the year during which treatments were made, whereas that on the Salem area was released after having had one growing season in the field. There were no replications within age on either of these areas. However, since the two areas were quite similar, it is quite possible that some of the differences in the behavior of the pine that received similar treatment on the two areas may have been due to the difference in the age of the pine.

The large difference between the 11 percent and the 88 percent mortality on the clear-cut plots on the Willow Springs and Salem Ranger Districts, respectively, was considered of sufficient importance to justify the initiation of another study to ascertain more definitely the effects of release on the mortality in shortleaf pine plantations of different ages. The response of pine to release was greater on the Willow Springs area than on the Salem area. Likewise, the variation of height growth of the pine released by the different methods was significant on the Willow Springs area and not on the Salem area. Since, within each method of release the height growth of the pine on the Salem area increased with an increase in intensity of release, and since the overstory was less dense on the cut plots than on those treated by notch and peel-girdling, this failure of methods to show significant differences in height growth was unexpected.

Although the releases discussed in this paper are spoken of in terms of light, it is recognized that soil moisture is also an important factor in the survival and height growth of planted pine. It is quite possible that the three methods of release employed in this study do not bring about corresponding reductions in competition for light and moisture. The increase in the rate of photosynthesis in pine per unit increase in light is greater at the lower than at the higher intensities of light. The fact that the removal of the last one-third of the overstory resulted in a greater increase in the growth rate of pine than did the removal of either the first or second one-third raises the question as to whether light is the limiting factor. Likewise, a difference in the light and moisture requirements for pine during the first and second growing seasons after planting may explain the differences in growth

rate of the pine on the two areas. It is possible to obtain some practical information on the release of pine by considering light and moisture collectively. However, if the differences in the behavior of released pine are to be fully explained, it will be necessary to consider light and moisture separately and find out to what extent each is a limiting factor.

## Summary

The behavior of the 1-0 shortleaf pine planted on the Willow Springs Ranger District in the spring of 1938 and released by cutting, notch-girdling and peel-girdling the overstory trees during February, May and August of the same year is summarized as follows:

(1) The height growth of the pine varied directly with the length of the growing season after treatment.

(2) The growth rate of the pine varied inversely with the density of the overstory brought about by the three methods of release.

(3) Although the mortality of the pine was increased 60 percent by treatment, the variations between seasons within each treatment and between treatments within each season were not significant.

On the Salem Ranger District the 1-0 shortleaf pine was planted in the fall of 1936 and was released in the spring of 1938 by cutting, notch-girdling and peel-girdling 0, 33, 67, and 100 percent of the overstory. The pine responded as follows:

(1) The height growth of the pine increased with an increase in the intensity of release for all three methods.

(2) In each instance treatment of the last one-third of the overstory resulted in a greater increase in height growth than did treatment of either the first or second one-third.

(3) The variation in height growth of the pine between methods was not significant within any of the intensities of treatment.

(4) The mortality of the pine was tripled by release due primarily to the unexpectedly high mortality on the plots released 100 percent by cutting.

(5) Release of pine the same year it was planted resulted in a greater increase in height growth and a lower mortality due to treatment than when released after having had one growing season in the field.

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Station Note
No. 36

August 15, 1939.

# SITE INDEX CURVES FOR PLANTATION BLACK LOCUST

## CENTRAL STATES REGION

By

Leonard F. Kellogg
Silviculturist

Black locust (Robinia pseudoacacia L.) was planted very commonly about thirty-five years ago and even prior to that time. More recently there has been a reawakened interest in this species which has resulted in planting it by the millons. What will be the development of this tree on various site qualities?

As a guide, we are fortunate to have these older plantings whose development provides a dependable index to the expected height growth of young plantings on various soils and sites. As a basis, some 170 plots were measured by this Station in 1931 and 1932. From these plots, age and dominant heights have been compiled to provide the attached set of site index curves. In their preparation, an equation was solved based on average dominant heights and corresponding ages. A curve of standard deviation over age and one of coefficient of variation were also prepared, following the technic of Osborne and Schumacher[1] to control the spread of the curves. Proper substitutions in the equation provided this sheaf of curves.

Although few of the stands are undisturbed through 50 years, this age was used for site classification because preliminary computations on the basis of 25 years spread the curves excessively. Using the older age, the data provide for the segregation of seven 10-foot site index curves.

Inspection of the plots spotted on the curves will show a notable thinness of representation in the 30 to 50-year age classes. The lack of plantations of these ages very likely may be traced to the utilization of superior larger plantings on the best sites, and the removal of the short borer-riddled, misshapen stands for firewood on the poorest sites.

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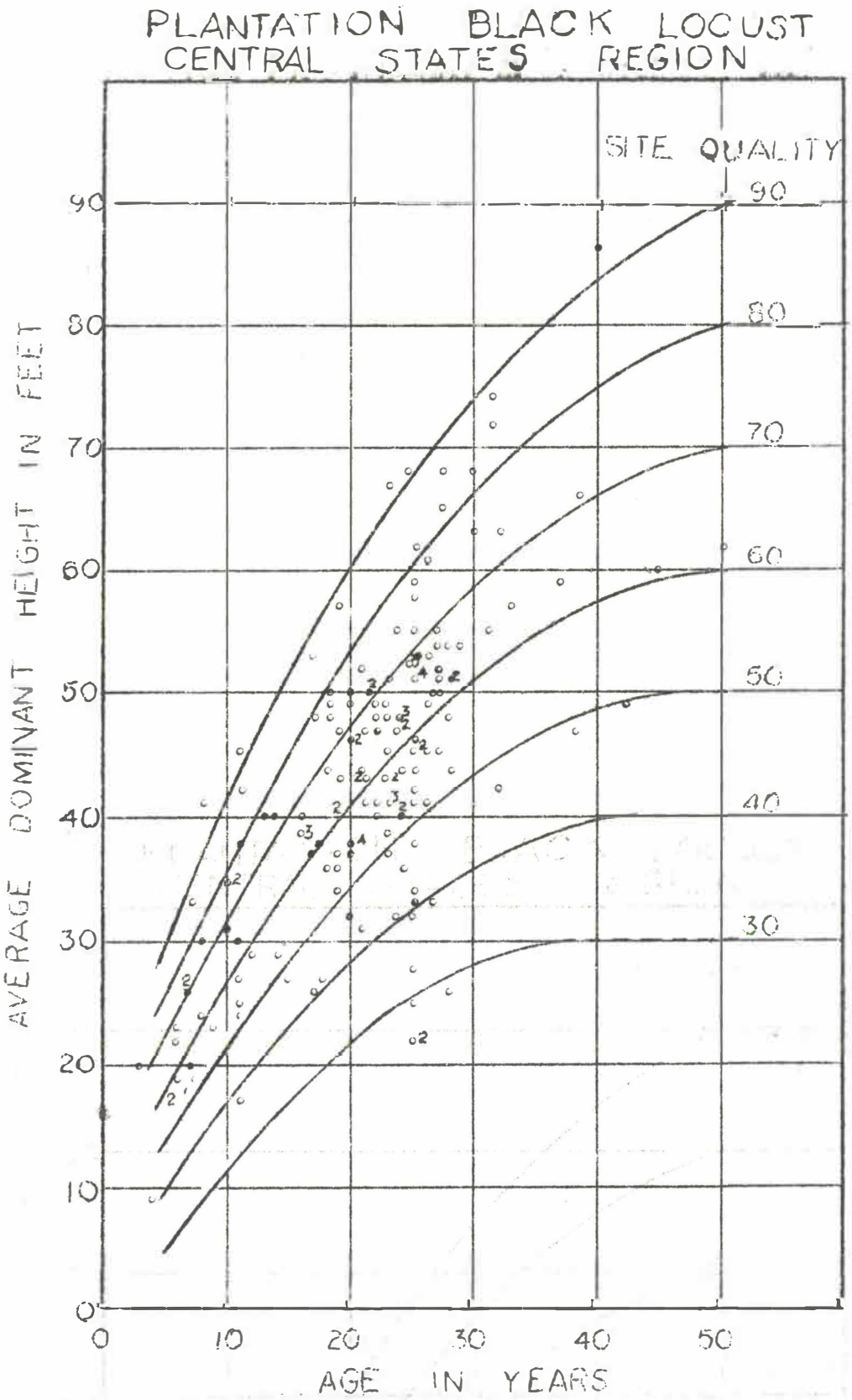
[1] Osborne, James G., and Schumacher, Francis X. 1935. The Construction of Normal-Yield and Stand Tables for Even-Aged Timber Stands. Jour. Agri. Res. Vol. 51 (6): 547-564. Bibl. Graphs.

The plantings on which these curves are based occur over Ohio, Indiana, and Illinois, with a sparse representation from western portions of Kentucky and of Tennessee. These curves may be considered representative of the performance of black locust within this region. Most stands contained a varying amount of infestation with the locust borer (Cyllene robiniae), so that it should be considered a normal condition in black locust plantings in this region.

It should be especially noted that these curves are not suitable for application to stands of sprout growth. Stands of stems originating from extensive well-established locust root systems grow more rapidly and possess habits of development which differ from those of more slowly-growing seedlings.

To use the curves, determine the age and average dominant height of the stand in question. By plotting this height over the appropriate age, the locust stand may be readily identified with respect to the nearest site curve. A projection of its location with respect to this curve forward to 50 years will provide the approximate site index of the plot, and the height to which it may be expected to develop at that age.




DISTRIBUTION OF YIELD PLOTS WITH RESPECT TO HEIGHT CURVES BY SITE QUALITY CLASSES

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Station Note
No. 35

June 22, 1939

# SITE INDEX CURVES FOR PLANTATION BLACK WALNUT

## CENTRAL STATES REGION

L. F. Kellogg, Silviculturist

Reliable information on the development of plantations of trees and particularly for hardwoods is greatly needed. Among the species used in early pioneer plantings in the Middle West, black walnut is very prominent. Because of its very high value and genuine intrinsic worth, this species has been studied in detail. Although it occurred originally as huge, scattered individuals in half open stands, and particularly on fertile, moist, alluvial lands, planters frequently have established it in pure stands, at close spacings, on uplands and edaphically out of its proper environment.

In order to determine the height growth for black walnut planted in pure stands, data from some 188 plots have been assembled. From these data the attached site index or site quality curves were prepared. A curve of average dominant height over age was drawn and used in the construction of a percentage alinement chart, following the technic of Reineke.[1] The age of classification was placed arbitrarily at 50 years.

The range of height growth of black walnut in pure plantations in the Central States Region is broad enough to permit the identification of five 10-foot site quality or index classes at 50 years. Eighty feet at fifty years is the best development to be expected ordinarily. Outside of this region, very limited areas in the Cumberland mountains at the bases of slopes showed better growth which had a site index of 90 to 95 feet. It seems probable that occasional better site qualities may appear in the future; but the likelihood of their occurrence on the open prairie lands is very slight. Farther west, in eastern Nebraska and Kansas, poor development is to be expected because of lower rainfall, exposure and dessication. Lower site qualities than those indicated by these curves probably occur under such conditions.

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1/ Reineke, L. H. 1927. A modification of Bruce's Method of Preparing Timber Yield Tables. Jour. Agri. Res. Vol. 35 (9):843-855.

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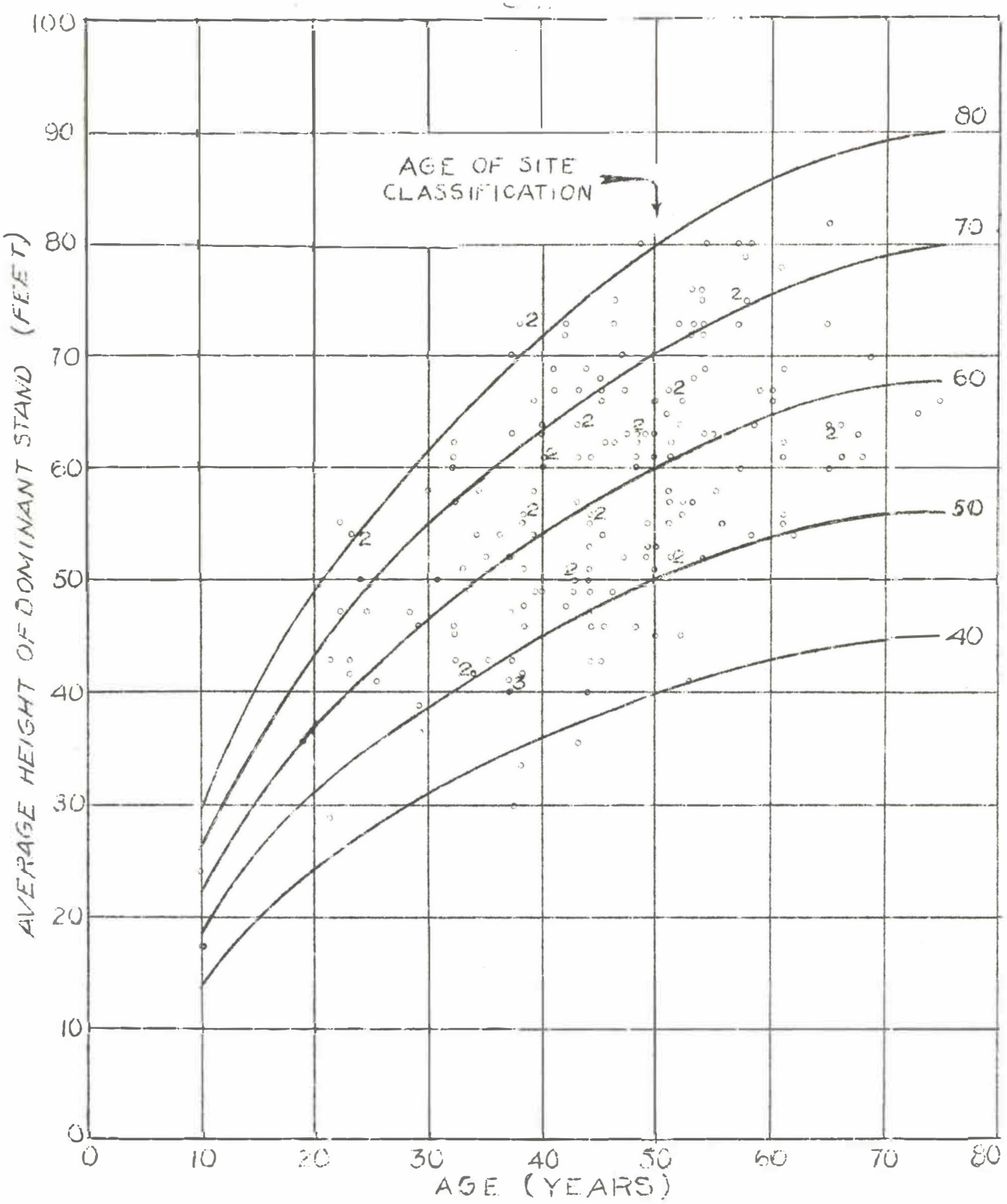
These curves may be used to determine the site quality for any given walnut plantation. To do this, only the age and average dominant height of the plantation must be determined. By plotting in this point, the planting is readily identified with the closest of the several curves. Furthermore, the site index of the plantation in question may be easily approximated. For example, a 35-year-old planting with an average dominant height of 45 feet would locate about four tenths of the way between the 50 and 60 foot site index curves. By projection to 50 years, using the 50 foot site curve as a guide, the planting will be found to be about 53 feet high, its site index. These curves can be used with reasonable assurance to predict the growth of black walnut on similar soils.

This is the first of several releases which may be made prior to the appearance of a complete report on the performance of this species in plantations in this region.

PLANTATION BLACK WALNUT

CENTRAL STATES REGION




DISTRIBUTION OF YIELD PLOTS WITH RESPECT TO HEIGHT CURVES BY SITE INDEX CLASSES

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Columbus, Ohio

Station Note
No. 34

December 1, 1938

# SOIL MOISTURE CONTENT DURING CRITICAL PERIODS IN THE REGENERATION OF PREVIOUSLY GRAZED FARM WOODLANDS*

By Oliver D. Diller

One of the most interesting observations resulting from studies of the regeneration of farm woods following continued overgrazing has been the apparent static condition of certain areas over long periods. These studies, cooperatively made by the Central States Forest Experiment Station and the Purdue University Agricultural Experiment Station (4), indicate that many woodlands which had deteriorated to the point where a complete sod cover had become established were incapable of natural recovery within a reasonable length of time. In these open areas, whenever the proper coincidence of seed crops and conditions favorable for germination occurred, tree seedlings gained a start in the spring, but during the dry summer a very high mortality often took place, and by the following season the seedlings had usually disappeared from the area.

These preliminary observations were followed up by supplementary intensive ecological studies which were carried on in a number of northern Indiana farm woods. The conclusion reached following three seasons of observations and periodic measurements (5) was that soil moisture is the principal limiting factor in the satisfactory regeneration of these grazed woodlands which have reached the advanced stages of decadence. Woodlands in which a complete sod cover has been established through the partial opening up of the stand probably suffer a greater loss of soil moisture than woodlands in any other stage in the transition from dense forest to open pasture. This has been attributed to the cumulative effect of increased transpiration and evaporation in these "open park" woods. The factors which tend to conserve moisture have been materially disturbed through the compacting of the soil surface (1), the disappearance of the protective forest litter, the elimination of the shrubby undergrowth and tree seedlings which served as an effective barrier against free wind movements, and the formation of a sod cover. On the other hand, the tremendous amount of transpiration which takes place in the dense forest has been only moderately lowered through the reduction in the number of trees.

Important problems in the management of these areas obviously hinge on the soundness of this hypothesis, and in order to secure definite quantitative data a series of soil-moisture determinations were made by the writer, with the assistance of Mace Raymond, of the Purdue Agricultural Experiment Station, during the summer of 1935. These studies were made in the oak-hickory type on a Miami silty clay loam in Grant County, Ind. Soil moisture determinations were made weekly in the A, B, and C horizons of an open grazed woods, and also in an adjacent fully stocked woods and an open pasture.

*Reprinted from Journal of Forestry
Vol. XXXV, No. 4, April, 1937

ificant in the chart. That is that the soil-moisture content in the A and B horizons in the open field was in practically every case higher than in either of the other two habitats. From these data, which were obtained during the growing season only, it would appear that the benefits of decreased run-off and evaporation (8) and increased water-holding capacity of the soil under a forest cover (1) are partially or entirely outweighed, so far as available moisture in the upper horizons is concerned, during the summer months by the tremendous amount of transpiration which takes place in the forest. According to Craib (3), Ebermayer has shown that forested areas of pine and beech contained considerably less soil moisture than open areas during all four seasons of the year. Zon (10) also points out that in level country forests tend to lower the water table and reduce the soil moisture to a greater degree than other forms of vegetation. Bates (2) has recently published data obtained from lysimeters which demonstrated that the real period of ground-water replenishment is in the winter and spring. From July to December, the lysimeters did not yield a drop of water despite a total rainfall of 18.18 inches. The apparent counter trend in the C horizon, where the moisture content is in two instances higher in the ungrazed woodland, is quite possibly due to greater water storage in the lower horizons during the dormant season. Since soil seldom freezes under forest litter and forest soil is much more porous, it is reasonable to believe that percolation occurs to a greater depth than in open areas, where no percolation is possible while the ground is frozen. Since it is generally believed that the upper horizons supply most of the water requirements of trees and that lateral movements of soil moisture in level country occur at a very slow rate, it would appear that this concentration at the lower depths might be rather stable throughout the season.

It is fully appreciated that the results of this study, covering only one season of observations, are inconclusive, but they have served to establish a rather definite relationship between the very critical soil-moisture conditions which exist in the open grazed woodlands during the mid-summer drouth periods and the repeated failure of natural regeneration in many of these areas. Further quantitative data are needed to determine the influence of forest cover on ground-water supplies in the Corn Belt region.

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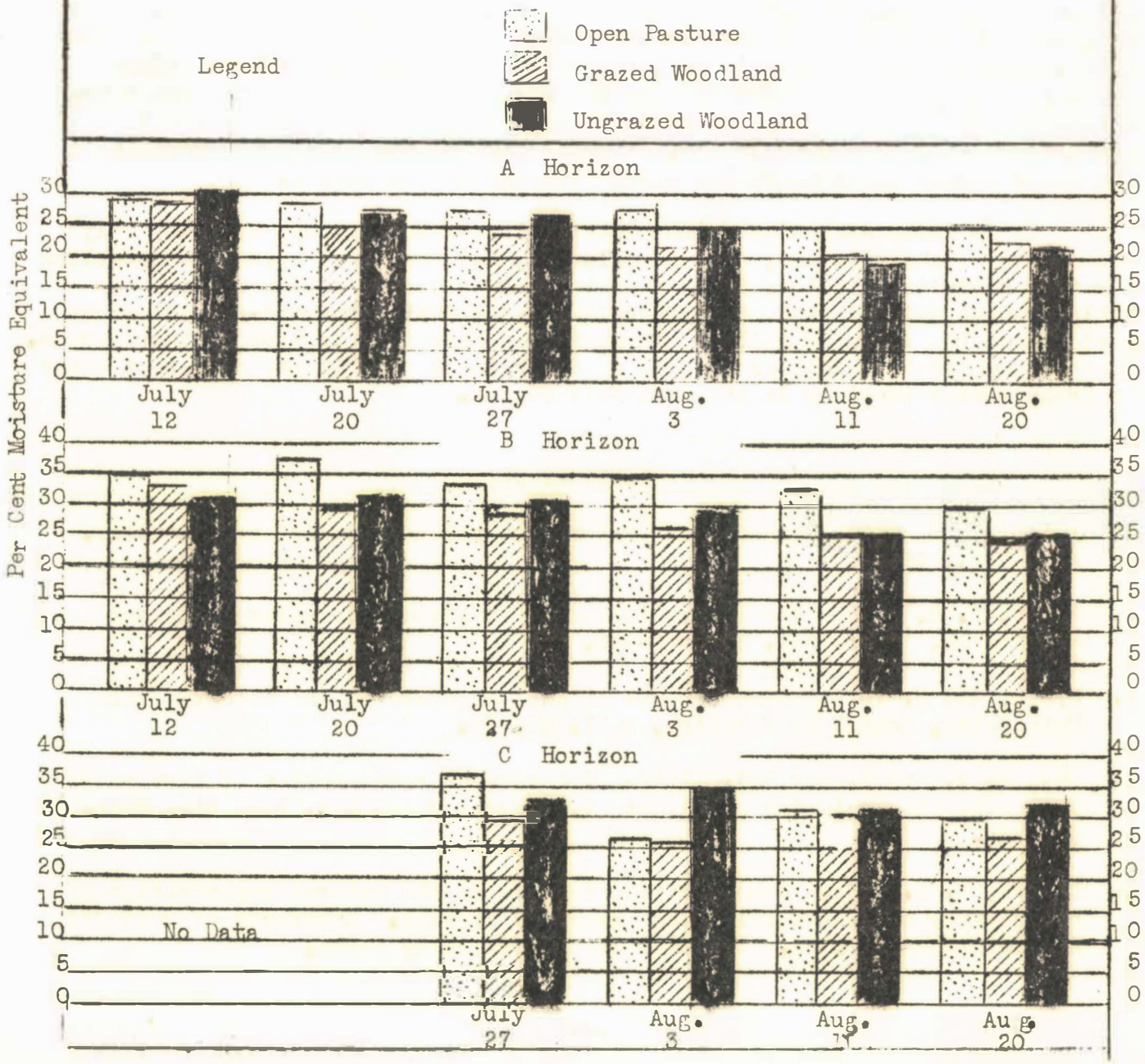
Fig. 1.--Soil-moisture conditions in a fully stocked oak-hickory woodland, open grazed woodland, and blue-grass pasture. McVicker farm, Upland, Ind., summer of 1935



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Station Note
No. 33

November 15, 1937

# A METHOD OF SITE EVALUATION FOR YELLOW POPLAR BASED ON DEPTH OF THE UNDISTURBED $A_1$ SOIL HORIZON

By

John T. Auten, Silviculturist

A recent study of yellow poplar growth as related to site conditions in the Central States (Station Note No. 32) has indicated that depth of penetration of organic matter in the surface soil may be a good index to site quality. Accordingly this progress report has been prepared as an aid to foresters in recognizing areas where this species should be favored in forest management, or where it could be planted with reasonable chances of success.

Yellow poplar has been found to grow best on deep, moist but well drained soils, and poorly or not at all on dry, exposed sites and on heavy, wet soils. It also happens that the same conditions which favor good yellow poplar growth are largely responsible for maximum organic matter accumulation and incorporation in the surface soil under normal, undisturbed conditions.

There is great variation in the depth to which organic debris becomes incorporated normally into the surface soil. Within the range of yellow poplar in the Brown Forest Soil Province of the Central States this depth may vary from no incorporation, with visible evidence of soil leaching, to twelve inches or more. The reasons for this variation become more or less obvious if we consider conditions under two extremes of site - moist, sheltered coves or bottoms in contrast with dry, exposed ridges.

Sites most favorable to vegetative growth produce the most luxuriant foliage and hence the most litter. In his soil study of the Mont Alto State Forest (Penna. Research Bull. 4) the writer found that the annual leaf-fall on cove, slope, and ridge sites averaged 5500, 3600, and 3000 pounds per acre, respectively. Furthermore, litter blown about the forest floor has a tendency to shift from dry, exposed slopes and ridges and accumulate in sheltered, moist sites. With this greater accumulation comes more complete incorporation by soil fauna because moist sites are more favorable for their existence and activities. Although litter decomposition is more rapid in moist than in dry soil, the type of decomposition with moisture favors humification and preservation of the carbonaceous portion in contrast to its loss through slow oxidation on exposed ridges and on hot south slopes, where litter destruction by fire is also most frequent. Retention of organic matter is favored in finer-textured soils, and cove or bottomland soils are generally finer in texture than ridge and slope soils because differential erosion

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from varying surface run-off velocities tends to segregate particle sizes, and deposit the finer textured particles on the lower and more level areas.

It follows that those factors which favor organic matter incorporation likewise favor occurrence and growth of certain tree species, including yellow poplar. The fact that yellow poplar is found commonly in coves and on north slopes where the deepest organic or $A_1$ soil horizons are developed indicates a direct relationship. Indeed this relationship of $A_1$ soil horizon depth to tree occurrence and growth exhibits its extreme manifestation not only in differences in growth rate but even in changes in forest species composition. The basic assumption, then, is that depth of organic matter incorporation representing its production, decomposition, and incorporation is an index or integration of all the meteorologic, biotic, and pedologic factors of site which influence tree occurrence and rate of growth.

In this study of yellow poplar site requirements, preliminary analysis of the data for 78 plots showed a substantially linear relationship between mean annual height growth and depth of the $A_1$ horizon. The range of $A_1$ horizon depths was from 1 to 12 inches and the height-age ratio of trees was from .64 foot to 4.0 feet. The evidence was rather convincing that yellow poplar will not grow successfully on sites whose original or potential $A_1$ horizon is less than 1 inch deep; that the rate of tree growth increases directly with the $A_1$ potentialities of the site; but that any $A_1$ depth over 10 inches is either ineffective or indicative of swamp or prairie conditions to which yellow poplar is not indigenous.

As the result of a further refinement of the statistical analysis by the Bruce and Reineke method (USDA Tech. Bull. 210) the accompanying alinement chart is offered as a means of evaluating yellow poplar sites. If the major premise holds as true under all field conditions as the statistical analysis indicates, then this method should be applicable universally in the region and may be developed for species other than yellow poplar. This method of site appraisal should be found useful in the management of existing stands where questions arise as to choice of species which should be favored, as well as in selecting sites for planting yellow poplar.

The correlation of tree growth with depth of organic matter penetration naturally stimulates conjecture whether growth of yellow poplar is accelerated by the soil organic matter or whether the organic matter is merely incidental as a result of site conditions favorable to its accumulation as well as to tree growth. If yellow poplar would not reseed, become established, and thrive on any soil but that with a plentiful supply of organic matter, it might be concluded logically that growth of the species depended on it. However, yellow poplar often reproduces and grows rapidly on old fields whose surface organic matter has been

removed by erosion and oxidation. Once established on such areas, in a comparatively short time it produces enough litter to enrich the upper soil with organic matter in an amount commensurate with the initial productivity of the site. Numerous yellow poplar stands have been observed which, in the memory of the owners, have reseeded and developed well on abandoned fields. The organic matter penetration in these areas has been so rapid and to such a depth that the plow depth is now determined with difficulty. There is no doubt that the deposited organic matter influences growth rate in a cumulative manner as it grows in amount, but its presence is largely a result and not a cause.

Since many of the areas with which foresters must deal are no longer in normal condition, and the original organic matter layer may have been disturbed or obliterated by clearing and cultivation or by destruction of good forest conditions by excessive cutting, grazing, or fire, it becomes necessary to keep in mind that this method of evaluation is based upon the potentialities of the site as indicated by the original penetration of organic matter. Often the original $A_1$ horizon depth may be approximated along a fence row or in a clump of woods adjacent, where the soil has remained undisturbed. If neither of these alternatives is available, then measurements may be taken on the nearest site where conditions are similar to those under consideration. Due regard should be given to similarity of aspect, exposure, altitude, and soil profile with the area under consideration.

Situations may be encountered where extreme erosion may seem to render prediction difficult, but it must be remembered under these circumstances that yellow poplar never thrived over tight, poorly drained subsoils or on excessively dry sites even in the virgin forest, nor was a deep $A_1$ horizon developed under such conditions. Yellow poplar occurred in virgin stands on deep, moist, well-drained soils. Whatever change erosion brings about on a deep, immature soil profile is for the most part only a temporary surface phenomenon, but it may make tree establishment somewhat more difficult. Numerous yellow poplar stands have been found mixed with sassafras whose ages indicated that the latter species first occupied the site; then yellow poplar seeded in and became dominant. In reforesting particularly difficult areas, it may be necessary to start with some species adapted to establishment under difficult surface soil conditions even though the area may be a potential yellow poplar site. Yellow poplar may follow later when surface soil conditions suitable for its establishment have been restored.

## Statistical Analysis of Data

Departing from mean annual height growth, age, and depth of the $A_1$ horizon, the three variables used in the preliminary analysis, height in feet, age in years, and depth of the $A_1$ soil horizon in inches were substituted. The multiple correlation coefficient of the three variables; height of stand in feet, age of stand in years, and depth of the $A_1$ soil horizon in inches from 78 plots, assuming straight line regression, was .70. The regression equation was: (Height of stand in feet) = 1.125 (Age of stand in years) + 2.62 (Depth of $A_1$ soil horizon in inches) + 23.06 feet. The Standard Error of Estimate was 12.12 feet. On the basis of the first estimate from which this equation was derived, the partial regression coefficient of $A_1$ soil horizon depth, 2.62, by Fisher's "t" test was highly significant. This coefficient signifies that for each inch of increment in $A_1$ soil horizon depth there was an increase of 2.62 feet in height of the average-aged stand. Since plotting of the data disclosed curvilinearity for both height-age and height-$A_1$ soil horizon depth relationships, the Bruce and Reineke method of graphical correction was used. This resulted in a correlation index of .78 with a standard error of estimate of $\pm$ 10.6 feet. The final estimate by this method gave an alienation index of .63 which squared and subtracted from unity indicated that approximately 60 per cent of variation in height was explained by age and depth of $A_1$ soil horizon.

ALINEMENT CHART SHOWING HEIGHTS OF
YELLOW POPLAR
ON SITES HAVING VARYING A-1 SOIL HORIZON DEPTHS
BASED ON NORMAL ORGANIC MATTER
INCORPORATION

INTERMOUNTAIN STATION
Central Reference File
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# SITE REQUIREMENTS OF YELLOW POPLAR

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An understanding of the site requirements of tree species and an appraisal of soil conditions for any given site are essential to successful forest management. Knowledge of soil and site conditions is especially necessary before forest planting is attempted, because even slight variations may make all the difference between success and failure.

This investigation of yellow poplar site requirements is a continuation of the soil profile-tree type study begun with black locust and black walnut and published as Station Note No. 31 (1).* It is preliminary in nature in that it is a part of a comprehensive study to be continued and extended to other species. This progress report may be modified in certain details as the study advances and will be incorporated eventually in a final report on the soil-tree type relationships of the region.

Plan of Study. The area covered in this investigation includes southeastern Ohio, Kentucky, Tennessee, southern Indiana, and southern Illinois. This region extends from the optimum range of the species to its western limit near the Mississippi River. Seventy-eight plots were taken at random wherever stands of yellow poplar could be found. Circular plots were established, usually 1/4 acre in size, but it sometimes was necessary to use 1/8-acre or 1/16-acre plots to take advantage of small tree groups. Plots were selected where severe fire and grazing had not occurred and scattered trees growing under pasture conditions were avoided. Most of the plots studied were even-aged, second-growth stands which had come in after lumbering operations; some had regenerated on old, abandoned fields. The plot ages varied from 12 to 61 years with 63 per cent of all plots between 25 and 45 years of age.

In the 1/4-acre plots 10 dominant trees, and in the 1/8 or 1/16-acre plots never less than 5, were measured as a basis for determining mean annual height growth which ranged from .64 to 4.0 feet according to site quality. The heights and diameters of the even-aged dominant trees in each plot were very uniform. Slope per cent, aspect, exposure, and other supplemental data such as natural tree association, natural regeneration, and condition of the stand were recorded. The soil on each plot was examined for depth of horizons, penetration of organic matter, color, texture, structure, reaction by the quinhydrone electrode, replaceable calcium, magnesium, phosphorus, and potassium. All chemical tests were made in the field by the use of a portable laboratory mounted on a 1/2-ton truck chassis.

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* Figures in parenthesis refer to literature cited.

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## ANALYSIS AND DISCUSSION OF DATA ON SOIL PHYSICAL PROPERTIES

Drainage of the Site. Drainage of yellow poplar plots was estimated relatively in the field and classified as excessive, good, fair, poor, or very poor, according to the character of the soil profile, topography, geological strata, proximity of drainage systems, kind of ground cover, and similar factors. Drainage proved very significant in the analysis of the yellow poplar growth data. Only 9 of 78 plots were recorded as fair to poorly drained, and 3 of these had been planted. All others were recorded as well drained. The average annual height growth of these 9 poorly drained plots was 1.61 feet, - much less than the average for the moist but well-drained plots. Apparently yellow poplar will not grow successfully on poorly drained soil. Moreover, no yellow poplar stands were found on excessively drained sites and those on soils which tended to be dry were growing at a very slow rate.

Texture of the Soil. Of a total of 78 yellow poplar plots, there were 15 whose surface or A horizon were of finer texture than silt loam. They fell for the most part into the silty clay loam class. Several of them had a thin $A_1$ horizon with a texture of silt loam, but below this and above the true B the texture was silty clay loam. All plots whose texture was silty clay loam or heavier in the A horizon, were classed as heavy surface soils. The average annual height growth figure for this class was 2.24 feet. The fastest growing plot in the entire list had a silty clay surface, but its soil was residual from limestone and had a crumb structure. Another plot with a silty clay surface soil had an annual height growth of 3.2 feet. It cannot be said that, on the basis of texture in the surface soil, the heavier soils are inferior. They may or may not be, depending whether the structure is such as to counteract the effect of heavy texture on drainage and aeration or whether the heavy surface soil is also accompanied with a heavy subsoil.

As far as the subsoil is concerned excessive concentration of the fine textured fractions in the lower stratum is deleterious to successful growth of yellow poplar. One particular plot might be pointed out whose average annual height growth was only .64 foot. The subsoil in this plot is a tight drab clay (2). The site is dry because the possible water storage is diminished, and in time of drought the roots are cut off from ground water supply. Within a hundred feet of this plot is another of the same age whose annual height growth is 2.1 feet. The only apparent difference in the two is variation in subsoils. The fertility of the two surface soils is practically the same. A tight subsoil, particularly if it is near the surface, lessens water-holding capacity of the profile. Badly exposed sites with tight subsoils or excessively drained profiles constitute the most adverse conditions for growth of yellow poplar.

Tight subsoils are usually characteristic of mature soils. In general, immature soils in this region are found in steeply dissected terrain where the parent material is sandstone or shale - more often the former (6). The stages of soil maturity have significance to the forester in that they indicate different degrees of drainage and aeration. Speaking generally, a soil in a flat region which has developed an X or Y horizon (3) is likely to be inferior for the growing of yellow poplar to a soil in a rougher region

where the deep consolidated horizons have not formed. And in any given local area where examination shows the presence of a deeply weathered horizon, tree species which demand a well drained soil should be avoided.

Color of Subsoil. This study indicates a relationship between subsoil color and growth of yellow poplar in the Central States similar to that determined in the study of black locust and black walnut (1). By classifying plots as to subsoil color based on a scale varying from blue to reddish brown, it was demonstrated that sites which had subsoils tending in color toward the reddish brown end of the scale were capable of supporting much better growth of both locust and walnut than were those whose subsoils were at the drab or blue end of the scale. In this Brown Forest Soil Province* the brown and reddish brown soils are well oxidized and well drained, whereas if a soil has a high water table throughout a large part of the year, it will gradually become reduced and the oxides of iron will be blue instead of brown or red. All gradations occur from the waterlogged profile with a dense drab or blue subsoil to the friable, well-drained, reddish brown, immature profile whose B horizon has not developed.

In this study of yellow poplar distribution of soil color was found to be toward the reddish brown end of the scale. Out of 78 plots there were only six having gray, drab, or gray-mottled subsoils and three of these were in plantations. It is significant that the average annual height growth on these gray and mottled subsoils was only 1.47 feet. The first plot (.64 foot annual height growth) was in the Muskingum soil area, but was locally underlain with a tight, blue-drab clay. The second and third plots (2.1 ft. and 1.5 ft.) were within the area of Illinoian glaciation of southwestern Ohio and had mature profiles with gray-mottled subsoils and well developed X horizons (3). The fourth and fifth plots (1.8 ft. and 1.4 ft.) growing on the loess covered limestone residual soil of Hardin County, Illinois also had gray-mottled subsoil. The last in this group (1.4 ft.) represented a yellow poplar stand in western Tennessee growing on a terrace of ash-gray silty clay loam which had been covered with two feet of reddish brown sandy loam washed from Lexington soil above. It is significant to note that the plots were taken at random wherever poplar could be found and yet only three natural stands occurred on gray or mottled subsoils, and these were making an average annual height growth of only 1.5 feet. These growth rates are near the minimum recorded in this study for any part of the region.

Depth of Horizons. There was no apparent correlation between total depth of the A or surface soil horizon and annual growth of yellow poplar. The same was true of the B horizon depth. This latter is logical if we assume the important property of the B horizon is its ability to permit or hinder movement of water and air through the soil column. In this case the effectiveness of a B horizon would depend not on its mere thickness, but on its density. Obviously, a dense B horizon 2 inches thick might be more effective in retarding water or air movement than would a relatively loose B two feet thick. We should not expect to find correlation between soil horizon depth and growth unless we could, at the same time, appraise the density of the horizon with reasonable accuracy.

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* The Brown Forest Soil Province includes all of the region studied except a small area in western Tennessee and western Kentucky.

The failure to detect correlation between depth of the total A horizon and height growth of yellow poplar was coupled no doubt with the presence of so many immature soil profiles of the A C variety. In these cases, the division between the A and the C horizons is so uncertain that the differences as measured are not significant. There seems to be little doubt that a deep A horizon is superior for the growth of almost any of the upland hardwoods; it was so for black locust. If one had an array of data including all depths of A horizons, he would undoubtedly be able to trace a clear relationship. As for that matter, from the standpoint of aeration and water relationships, one would not be far wrong in calling an A C soil simply one with a very deep A horizon, in which case the effect of the A horizon would be unmistakable.

## DISCUSSION OF ORGANIC MATTER

Depth of Organic Matter Penetration. Although no significant correlation could be determined between the total depth of the A or surface horizon, the depth to which the upper soil horizon was penetrated by incorporation of organic matter in this Brown Forest Soil Province (6) was closely related to the character of yellow poplar growth. This organic or $A_1$ horizon may be recognized by its darker color in contrast to that of the soil beneath. The depth of penetration ranged from a fraction of an inch to as much as 12 inches. It was deeper generally in cove than in slope or ridge soil and in north than in south slope soil.

Analysis of the data for 78 yellow poplar plots shows a substantially linear relationship between mean annual height growth and depth of the $A_1$ horizon. The range of $A_1$ horizon depths was from 1 to 12 inches and the height-age ratio, .64 foot to 4 feet. The correlation coefficient ($.53 \pm 05$) is highly significant. The standard error of estimate from the regression equation is .52 foot for the average annual height growth. This means that one may estimate probable growth rate of yellow poplar in the Brown Forest Soil Province from the regression equation and be accurate to within .52 foot per year. Parenthetically, it may be said that the range of accuracy is between 1 inch and 10 inches depth of organic matter incorporation. Not enough plots were available for depths less than 1 inch or above 10. The evidence is rather convincing that yellow poplar will not grow successfully on sites whose original $A_1$ horizon is less than 1 inch deep; and that any depth over 10 inches is either ineffective or indicative of swamp or prairie conditions to which yellow poplar is not indigenous.

The correlation of tree growth with depth of organic matter penetration naturally stimulates conjecture whether growth of yellow poplar is accelerated by the soil organic matter or whether the organic matter is merely incidental as a result of site conditions favorable to its accumulation as well as to tree growth. The amount of organic matter occurring in the soil is the result of an equilibrium between the amount produced and its rate of incorporation and decomposition. If yellow poplar would not reseed, become established, and thrive on any soil but that with a plentiful supply of organic matter, it might be concluded logically that growth of the species depended on it. However, yellow poplar often reproduces and grows

rapidly on old fields (7) whose surface organic matter has been removed by oxidation and erosion. Furthermore, as will be discussed later, yellow poplar is able to make maximum growth on moist sites whose supply of replaceable mineral elements is so low that it is extremely unlikely that fertility in the organic matter is responsible for the superior growth. Yellow poplar, once established on bare soil, in a comparatively short time produces enough litter to enrich the upper soil with organic matter in an amount commensurate with the initial productivity of the site. Numerous yellow poplar stands have been observed which, in the memory of the owners, have reseeded and developed well on abandoned fields. The organic matter penetration in these areas has been so rapid and to such a depth that the plow depth is now determined with difficulty. There is no doubt that the deposited organic matter influences growth rate in a cumulative manner as it grows in amount, but its presence is largely a result and not a cause.

## ANALYSIS AND DISCUSSION OF CHEMICAL SOIL DATA

Calcium. Use of the Universal Soil Testing System (8) disclosed great variation in amounts of replaceable calcium in all soil horizons of the yellow poplar plots. The amount of replaceable calcium in the soil did not seem to influence growth in the least as far as the statistical analysis could disclose. That there is a connection between yellow poplar litter and calcium content cannot be denied after analyzing the data. The calcium is merely incidental, however. Yellow poplar is able to grow on acid soil, gather lime, and deposit it in the litter. This litter accumulating on the surface will in time build up the calcium content of the surface soil until in some cases more than a ton per acre may be recorded on soil whose subsurface fails to give even a test for replaceable calcium.

Table 1 shows several examples of this kind. Kentucky Plot No. 30 has 100 pounds in the surface 2 inches (calculated on a 7-inch acre basis) and Kentucky No. 31 has 1,000 pounds. The site indexes* are high for both plots: 97 and 118. Again, Tennessee Plot No. 14 has 1,500 pounds of available calcium with a growth rate of only 1.5 feet per year and a site index of only 74. Plots 30 and 31 have no detectable calcium below 2 inches, whereas Tennessee Plot 18 has calcium at the rate of 1,000 pounds per acre in the 4 to 6-inch horizon and 400 pounds in the subsoil, yet the plots with no calcium below 2 inches are able to support a superior growth of yellow poplar. Many more examples might be given to illustrate this fact; only a small part of the 78 plots is given here.

Concentration of calcium in the surface horizon occurred almost without exception on yellow poplar plots. This is illustrated in the average amounts of calcium found in the various horizons of 78 yellow poplar plots:

*Site index (9) was calculated by the method of Osbourne and Schumacher and signifies height of stand at 50 years of age.

| Horizon Depth | Pounds of Calcium Per Acre |
|---|---|
| 0-2 inches | 1,427 pounds |
| 4-6 " | 398 " |
| 12-14 " | 291 " |

There is a much greater concentration of calcium than there is of magnesium in the surface horizon. As great a difference as 3,500 pounds per acre was recorded between the surface horizon and the soil immediately below it. Although large amounts of calcium in the surface soil are coincident with established poplar stands, the species will establish on acid soil and make good growth if other conditions are favorable.

Magnesium. No apparent correlation was found between amounts of available magnesium and rate of yellow poplar growth. An average of pounds per acre of available magnesium found in all plots in the 3 horizons is as follows:

| Horizon Depth | Pounds of Magnesium Per Acre |
|---|---|
| 0-2 inches | 33 pounds |
| 4-6 " | 46 " |
| 12-14 " | 29 " |

There is a slight trend in the amounts of available magnesium from the surface horizon downward which indicates moderate concentration of this element in the surface horizon. Magnesium is commonly associated chemically with calcium and it is interesting to note differences in the accumulation of those two elements.

Table 1 shows some of the variations which occur in magnesium content of soil under yellow poplar. For instance, Kentucky Plot No. 8, with an annual height growth of 3.4 feet per year and a site index of 89, has 100 pounds magnesium per acre in each of the 3 horizons, whereas Kentucky Plot No. 27, with an annual height growth of 4 feet and a site index of 105, has only 5 pounds of magnesium in the subsoil and a maximum of only 25 pounds in any horizon. Evidently, only very small amounts of magnesium are necessary for maximum growth of yellow poplar.

Phosphorus. It will be apparent from Table 1 that there seems to be no relationship between soluble phosphorus and growth of yellow poplar. Tennessee Plot No. 18 has 100 pounds phosphorus in the upper horizon with a height growth of 1.8 feet and a site index of 79, whereas Kentucky Plot No. 27 has very little in any horizon with a height growth of 4 feet per year and a site index of 105. The fact cannot be overlooked that in this case yellow poplar is able to grow at maximum rates where the amounts of phosphorus are exceedingly low. This indicates that the existing amount of this element is not limiting. If we can depend on the method, and it probably is about as accurate as any that has been devised, then the fertility requirements of yellow poplar are very low. Average pounds phosphorus per 7-inch acre are given below.

| Horizon Depth | Phosphorus Pounds Per Acre |
|---|---|
| 0-2 inch depth | 66 pounds |
| 4-6 " " | 73 " |
| 12-14 " " | 65 " |

Table 1

Growth and Soil Data From 12 of 78 Yellow Poplar Plots

Illustrating Contrasts in Growth Rates and Soil Differences

| Plot No. | Average Annual Height Growth in Feet | Site Index | Age | Aspect | Depth of $A_1$ Horizon | CALCIUM Pounds* per Acre — Sampling Depth In Inches | | | MAGNESIUM Pounds* per Acre — Sampling Depth In Inches | | | PHOSPHORUS Pounds* per Acre — Sampling Depth In Inches | | | POTASSIUM Pounds* per Acre — Sampling Depth In Inches | | | REACTION - pH — Sampling Depth In Inches | | | County |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 0-2 | 4-6 | 12-14 | 0-2 | 4-6 | 12-14 | 0-2 | 4-6 | 12-14 | 0-2 | 4-6 | 12-14 | 0-2 | 4-6 | 12-14 | |
| Ky. 8 | 3.4 | 89 | 12 | NE | 8 | 500 | 400 | 400 | 100 | 100 | 100 | 75 | 100 | 75 | 100 | 100 | 75 | 5.8 | 6.1 | 5.8 | Breathitt |
| " 16 | 1.6 | 70 | 42 | N | 2 | 0 | 0 | 0 | 2 | 0 | 5 | 25 | 0 | 5 | 0 | 50 | 0 | 6.5 | 6.0 | 5.5 | Calloway |
| " 21 | 1.3 | 67 | 52 | W | 1 | 200 | | 100 | 50 | 50 | 50 | 0 | 25 | 15 | 0 | 0 | 0 | 7.6 | 5.8 | 8.3 | Nelson |
| " 27 | 4.0 | 105 | 19 | N | 8 | 3000 | 1000 | 200 | 25 | 25 | 5 | 0 | 25 | 10 | 150 | 175 | 0 | 8.1 | 6.9 | 7.9 | Estill |
| " 28 | 2.6 | 85 | 27 | W | 3 | 1000 | 50 | 0 | 30 | 10 | 10 | 10 | 10 | 10 | 0 | 0 | 0 | 7.4 | 7.3 | 5.5 | Estill |
| " 30 | 3.2 | 97 | 22 | C | 2 | 100 | 0 | 0 | 25 | 25 | 25 | 10 | 10 | 0 | 0 | 0 | 0 | 7.3 | 7.0 | 5.4 | Wolfe |
| " 31 | 3.1 | 118 | 35 | C | 7 | 1000 | 0 | 0 | 25 | 25 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | 7.3 | 6.4 | 5.1 | Wolfe |
| Tenn. 13 | 1.8 | 82 | 45 | E | 2 | 1000 | 400 | 100 | 35 | 25 | 0 | 15 | 25 | 10 | 200 | 250 | 150 | 7.9 | 8.2 | 7.8 | Madison |
| " 14 | 1.5 | 74 | 49 | NE | 2 | 1500 | 0 | 50 | 25 | 15 | 10 | 25 | 25 | 10 | 175 | 100 | 125 | 8.3 | 6.9 | 5.6 | Henderson |
| " 15 | 1.5 | 71 | 46 | W | 1 | 1000 | 0 | 0 | 7 | 5 | 25 | 5 | 5 | 10 | 150 | 50 | 0 | 7.5 | 5.3 | 5.1 | Dickson |
| " 18 | 1.8 | 79 | 43 | NW | 5 | 750 | 1000 | 400 | 25 | 25 | 10 | 100 | 10 | 5 | 175 | 250 | 50 | 8.0 | 7.7 | 6.1 | Dickson |
| " 19 | 1.5 | 88 | 59 | N | 1 | 1000 | 100 | 0 | 25 | 25 | 25 | 10 | 5 | 5 | 250 | 150 | 175 | 8.3 | 7.1 | 6.3 | Montgomery |

* Calculated on the basis of 2,000,000 pounds per acre for the surface 7 inches.

An interesting fact may be observed in the apparent lack of concentration of phosphorus in the surface horizon. On the basis of averages of all plot data, phosphorus is the only element which fails to show surface concentration. Possibly this may be explained on the basis of phosphorus withdrawal into the tree from the leaves before abscission in the fall.

Potassium. What has been said regarding phosphorus may equally well apply to potassium. Apparently there is no relationship between recorded potassium content of the soil and the growth of yellow poplar. Indeed in some instances, as with phosphorus, maximum growth occurred on soil too low in potassium to give a test. This was repeatedly so in those soils, such as Muskingum, which are derived largely from sandstone. Average pounds potassium for all horizons are given below. Each figure represents the average of 78 plot determinations.

| Horizon Depth | Potassium Pounds Per Acre |
|---|---|
| 0-2 inches | 130 pounds |
| 4-6 " | 72 " |
| 12-14 " | 40 " |

Soil Reaction. The following table gives a short summary of the data on soil reaction, for all yellow poplar plots.

| Horizon Depth | 0-2 in. | 4-6 in. | 12-14 in. |
|---|---|---|---|
| Plots below pH 7 | 21% | 71% | 90% |
| Plots below pH 6.5 | 8% | 47% | 85% |
| Plots below pH 6.0 | 2% | 31% | 74% |
| Average reaction | 7.35 | 6.45 | 5.74 |

If we consider pH 7 as neutrality, then the summary shows that only 21 per cent of all plots in the surface horizon fall below neutrality because of the concentration of calcium in the surface horizon. In the 4 to 6-inch horizon, however, 71 per cent of all plots fall below the neutral point, and in the 12 to 14-inch horizon, 90 per cent fall below pH 7. If we arbitrarily consider pH 6 as the point below which soil becomes decidedly acid, we see that in the surface soil only 2 per cent of the plots fall below that pH. If now we take the 12 to 14-inch horizon as the criterion of the normal condition of the soil independent of the influence of deposited organic matter, we see that a preponderant number of all soils examined are acid. Seventy-one per cent of all yellow poplar stands are on soil whose pH below 4 inches is acid. It is quite evident that at least a large portion of the roots of these trees are in acid soil. This fact, coupled with the observed reseeding of numerous poplar stands in old fields on acid soils where the organic matter is low and where in many cases the surface soil has been removed by erosion, is good evidence that the tree does not necessarily require a high pH or a large amount of calcium for its maximum growth. Indeed, it may be possible that acid soils are favorable to yellow poplar establishment.

Nitrogen. Owing to the fact that this report is preliminary in nature and that total nitrogen could not be determined in the field, a full report on this phase of fertility is not available at this time. However, as an illustration, two plots on which total nitrogen was determined gave an indication of its influence. Ohio Plot No. 4, age 19 years, with an average height

of 45 feet, was compared with Ohio Plot No. 5, adjacent, of the same age and with an average height of 10 feet. Total nitrogen in pounds per million pounds of soil was 1,290 and 1,200 pounds, respectively. These plots were within 200 feet of each other. Under the poor site was a tight clay subsoil; under the other, a deep, well drained profile.

The total pounds of nitrogen on the acre basis would, of course, be greater in the better site because of the greater depth of the $A_1$ horizon, but before attributing superior growth to nitrogen, one must answer questions regarding the reasons for the difference in depths of the $A_1$ horizon. In this case, there seems to be little doubt it was because of a tight clay subsoil under the poor site and not under the good site, thus making the former drier. Just as organic matter penetration is probably a function of soil moisture, so the total amount of nitrogen follows. The fact that yellow poplar will grow well on depleted soil of abandoned fields where organic matter and nitrogen supply are low indicates that large amounts of nitrogen are not necessary for maximum growth. It is likely that the nitrogen content of rainfall and that developed by nitrification on moist sites, even where organic matter content is low, supply sufficient nitrogen for good poplar growth. Nitrogen is necessary for tree growth as are all the other essential elements and no attempt to dismiss or even minimize its important role would be logical. However, in the light of the extreme importance of those properties of the soil profile which influence soil moisture supply, and in view of the very great influence of topography translated into aspect and exposure of the site, one must be cautious in attributing too much importance to any one element. Our previous study of black walnut and black locust failed to show that nitrogen was the limiting element of growth.

In the final report on soil profile-tree type relationship, the role of nitrogen will be given thorough consideration. There is great need for data on the minimum amounts of all the essential elements necessary for tree growth and this knowledge must be available before soil fertility can be used as a basis for predicting success of tree species on any site.

## DISCUSSION OF TOPOGRAPHY, ASPECT, AND EXPOSURE

Exposure of Site. The term exposure is used in the true sense of the word as it pertains to the absence of protection from some force or influence and not alone in the sense of aspect. In this particular case it carries not only the aspect phase of the word, but also position of the stand in the topography that may contribute to or deprive it of the protection of nearby hills or adjacent timber stands. This connotation of exposure, then, is any influence which tends to make the site a dry one. A category of six measures of exposure were used as follows: sheltered cove, open cove, sheltered slope, open slope, flat terrain, and ridges.

Every forester has observed that yellow poplar grows better in a sheltered site than it does in an exposed one. The differences in rate of growth in the exposure classes substantiate by concrete evidence for the region this commonly observed condition. Average annual height growth values for plots falling in each of the categories are arranged in Table 2. By analysis of variance, there was no significant difference between exposure classes; the

population was essentially homogenous. This eliminates question as to the possibility of certain age classes being concentrated in any exposure category. The table shows that the best growth of yellow poplar occurs on sheltered sites, and the poorest growth on exposed sites.

By separating the plots into two classes on the basis of their geographic location in the eastern or western part of the region, it is shown that the annual height growth in the eastern is greater than in the western. The difference in average annual height growth in the two areas is .63 foot (2.46 against 1.83). This difference by method of variance is highly significant; the probability that it could be a chance happening is less than one in ten thousand. The east and west averages arranged by exposure classes are as follows:

| | Cove Sheltered | Cove Open | Slope Sheltered | Slope Open | Flat Terrain | Ridge |
|---|---|---|---|---|---|---|
| East | 2.64 | 2.76 | 2.58 | 1.99 | | 1.40 |
| West | 2.60 | 2.30 | 1.82 | 1.86 | 1.65 | 1.60 |

While there is a distinct difference between growth in the two geographic regions, there is also a difference between growth in the exposure classes in each of the two regions. There is no factor more likely to be responsible for growth differences between exposure classes in a given region that that of moisture and it does not seem unreasonable to assume that the same factor is operative in creating the difference in growth between poplar in the eastern dissected region and the western flat to rolling region. Several decades of weather records show that there is more rainfall throughout the growing season in the eastern part of the region, whereas wind velocity is greater in the flat region to the West and this section is subjected to more severe desiccation. In the steeply dissected region of the Cumberland Plateau, fog and mist cling in the steep, narrow valley often until late morning, even in the summer time, and frequent summer showers are the normal occurrence. On the other hand, in the flat region of the West, the dew quickly dries on summer mornings and summer showers are not so frequent. There seems to be little doubt that soil moisture and atmospheric humidity are major factors in the growth rate of yellow poplar locally and regionally. Chapman (4) has well summarized these relations of forest distribution to topographic and climatic differences in this region.

Influence of Aspect. The aspect of a site in its influence on moisture is of great importance. This influence is clearly apparent in the changes of forest type or composition which occur on every forested area. In this particular region the north slopes generally are occupied by hardwoods with a leaning toward the mixed mesophytic. The south slopes and ridges are covered with variable mixtures from pure pine to oak-pine and often to the dry site oaks such as post, blackjack, scarlet, or scrub. The coves are commonly occupied by species such as walnut, ash, yellow poplar, gum, elm, etc., depending on the locality. There is little doubt that this difference in type is the expression of differences in soil moisture which in turn is

Table 2

Average Annual Height Growths of Yellow Poplar in Feet

78 Plots Grouped by Exposure Classes

| Sheltered Cove Feet | Open Cove Feet | Sheltered Slope Feet | Open Slope Feet | Flat Terrain Feet | Ridge Feet |
|---|---|---|---|---|---|
| 2.10 | 1.90 | 1.60 | .64 | 1.40 | 1.30 |
| 2.30 | 2.10 | 1.80 | 1.30 | 1.40 | 1.40 |
| 2.30 | 2.20 | 1.90 | 1.40 | 1.50 | 1.50 |
| 2.30 | 2.30 | 1.90 | 1.50 | 1.50 | 1.80 |
| 2.40 | 2.40 | 1.90 | 1.80 | 1.50 | |
| 2.60 | 2.40 | 2.00 | 1.80 | 1.50 | |
| 3.10 | 2.50 | 2.10 | 1.95 | 1.80 | |
| 4.00 | 2.60 | 2.20 | 2.10 | 1.90 | |
| | 2.60 | 2.20 | 2.10 | 2.00 | |
| | 2.80 | 2.20 | 2.20 | 2.00 | |
| | 3.10 | 2.30 | 2.40 | 2.10 | |
| | 3.20 | 2.30 | 2.70 | 2.15 | |
| | 3.40 | 2.40 | 2.80 | | |
| | | 2.50 | | | |
| | | 2.50 | | | |
| | | 2.60 | | | |
| | | 2.60 | | | |
| | | 2.60 | | | |
| | | 2.70 | | | |
| | | 2.70 | | | |
| | | 2.70 | | | |
| | | 2.80 | | | |
| | | 2.90 | | | |
| | | 3.00 | | | |
| | | 3.00 | | | |
| | | 3.20 | | | |
| | | 3.40 | | | |
| | | 3.50 | | | |
| Average 2.63 | 2.57 | 2.48 | 1.89 | 1.73 | 1.50 |

controlled largely by precipitation, temperature, and evaporation. If this difference in aspect will cause a change in tree type, and it is readily apparent that it does, then it should exert a marked influence on the average annual height growth of yellow poplar.

Such is the case. By grouping the plots on north and east slopes and in bottoms and coves recognized as the more moist sites, and the plots on

south and west slopes and ridges as dry sites, there is disclosed a highly significant difference in growth rates. The average annual height growth for the moist site classification was 2.39 feet, whereas that for the dry sites was 1.78. The difference of .60 foot is highly significant. The probability that it could have been a chance happening was about 2 to 10,000. This significant difference in the sites of respective classification can be credited more logically to different rates of soil moisture evaporation than to any other individual variable. Soil analyses of moist and dry sites do not always disclose significant differences in amounts of available chemical elements, and often other soil properties are uniform enough at least to partially eliminate the soil variable from consideration. The $A_1$ horizon is deeper on moist sites; however, the amounts of soil moisture are greater and the surface soil temperatures are lower on sheltered sites than they are on exposed sites. It appears that the limiting factor of poplar growth is probably in most instances soil moisture.

## SUMMARY

This is a progress report of one of a series of soil profile-tree type studies, begun with black walnut and black locust, which will be continued with similar studies of other species. The present investigation included 78 stands of yellow poplar in five Central States and involved determination of rates of growth and growth response to physical and chemical soil properties, aspect, exposure, and geographic location.

On the basis of careful analysis of the data, growth of these older stands of yellow poplar showed no correlation with amounts of available mineral elements in the soil. The fastest growing stands were found in sandstone and shale soils whose fertility level is probably the lowest in the region. These soils, because of the youthful character of their profiles and their position in steeply dissected terrain were generally moist, but well drained, and favored slower evaporation rates and lower soil surface temperatures.

Although no correlation was observed between amounts of mineral elements and growth of older stands of yellow poplar, fertilizer tests are now being made on seedlings and young trees to determine the influence on establishment and early growth. The very low requirement of trees for mineral elements indicates that a more sensitive chemical technique must be devised in order to find those amounts which are limiting to growth.

Depth of organic matter penetration in the surface soil horizon taken as the integration of meteorological and biological factors of site affords a valuable index to site quality evaluation for yellow poplar.

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# SOIL PROFILE STUDIES IN RELATION TO SITE REQUIREMENTS OF BLACK LOCUST AND BLACK WALNUT

John T. Auten, Silviculturist

Recent appreciation of land-use and conservation problems in the Central States has led to a greatly expanded public program of forest restoration. With the rapid increase in tree planting that ultimately may cover millions of acres of non-agricultural lands, it is necessary to select those species that will best serve the purpose of planting, whether it be for productive forest crops or for protective forest cover. It is essential that the selected species be adapted to the local conditions of climate, soil, and site; otherwise the planted trees cannot be expected to become established and grow successfully.

In the past many foresters have not given due consideration to the soil and moisture requirements of various tree species, nor to the changes of site caused by soil erosion and impoverishment that have taken place following removal of the virgin forest. In many instances it is no longer entirely safe to plant the species that formerly occupied the site. A large portion of the failures in reforestation may be attributed to lack of understanding of the site requirements of trees, and to the lack of suitable methods for appraising given site conditions before planting. In an effort to obtain this essential information, a study of soil properties correlated with tree growth has been started at the Central States Forest Experiment Station. This progress report summarizes the results of the first phases of the investigation.

Scope of Study. To initiate this study, the choice of two species extensively planted in this region, black walnut and black locust, gave promise of covering an extremely wide range of variations in the site requirements of upland hardwood species. It was thought that important soil and site conditions influencing growth of hardwoods would be brought to light, and that these might differ greatly between species. This preliminary study has resulted in a better understanding of conditions affecting moisture relationships which appear to exert great influence on the successful growth of hardwoods. A surprisingly similar reaction to these factors has been found for both species studied.

The black walnut plantation plots serving as the basis for this investigation were established by Kellogg (3) in 1928-1930, during a growth and yield study of black walnut in Ohio, Indiana, Kentucky, and Iowa. The black locust plantation plots were also established by Kellogg and by Hall (2) in 1930-1932, during their investigations of black locust growth and locust borer control, respectively. The locust plots were found from southern Michigan to southwestern Tennessee, and from western Illinois to eastern New York.

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The study consisted of collection and analysis of soil and site data from plantation plots for correlation with known rates of tree growth. The trees had been measured, their volume computed, and site index calculated for each of the locust and walnut plots. The accepted measure of site used in this study is the average height to which dominant trees grow in fifty years. As a check on this method of site quality evaluation, the volume yield of 100 plots was calculated for mean annual growth in cubic feet per acre, and correlated with the height-age site index. The correlation coefficient was .85 $\pm$ .02, indicating that the site index method provides a relatively reliable measure of site quality.

The soil data gathered from each plantation plot were divided into two parts - physical and chemical. In the study of physical factors the soil type was determined and the soil profile was examined for thickness, compactness, plasticity, texture, drainage, and color. The chemical study included determination of total nitrogen, organic carbon, water-soluble phosphorus, and acidity by the quinhydrone-calomel electrode method. Table 1 gives a sample of the data collected for a few of the 135 black locust plots and the 120 black walnut plots studied.

## Analysis And Discussion of Data on Physical Soil Properties

Soil Type. The results of this study have shown conclusively that soil types as mapped cannot be used indiscriminately as a criterion for evaluating site quality. In the broadest aspect a knowledge of soil types is valuable, but every soil surveyor knows that it is impossible to map all local variations within a soil type. Differences, especially of the properties and depths of the subsoil, are so numerous and diverse that the surveyor must set arbitrary limits of variation wide enough to cover the gamut of changes within the soil type. Slight variations in the soil are often critical factors in successful tree growth.

In general, certain of the lighter classes of soils, such as silt loams and sandy loams, predominated where the best growth of walnut and locust was found. The clays, silty clay loams, and heavier soils predominated in the poorer site range. If one could be sure of having the typical soil type as defined by the surveyor, he could place considerable credence on its forecasting possibilities as regards tree growth, but in many instances this cannot be ascertained without a detailed examination of each individual area. This is no reflection on the excellent work of the soil surveyor, who can supply the information needed if he has the opportunity to make the survey in the necessary detail.

Thickness of Soil Horizons. The thickness or depth of the surface soil (A horizon) is in general a measure of the cumulative effect of weathering, as well as of the extent of erosion, and should be a valuable indication of site quality. Analysis of the plot data shows that deep surface soil favors the growth both of locust and walnut. Apparently black locust is more susceptible to the influence of site deterioration than was commonly believed.

No relation was observed between depth of the subsoil (B horizon) and growth either of walnut or locust. This was to be expected, because mere thickness unrelated to compactness or plasticity means little in relation to aeration or drainage.

Subsoil Properties. Measurements of compactness, plasticity, drainage, and oxidation were taken only in the subsoil horizon. The A horizon or upper soil layer was entirely absent in some plots as a result of erosion, and in order to secure comparable data it was necessary to examine the lower horizons. The subsoil, with its accumulation of colloidal material, often more clearly records the status of soil evolution than does the surface soil. The color of the subsoil presents a clear picture of the extent of aeration and consequent oxidation. The character of the subsoil determines very largely how effectively the soil profile is drained. As far as physical structure is concerned, therefore, aside from the early period of tree establishment, it is the subsoil that most effectively influences growth.

An evaluation of compactness, plasticity, drainage, and oxidation was made on the basis of the following keys:

COMPACTNESS INDEX KEY

1. Non-coherent when moist - loose
2. Slightly coherent when moist
3. Mellow when moist
4. Friable when moist
5. Moderately compact when moist
6. Very compact when moist
7. Extremely compact when moist

PLASTICITY INDEX KEY

1. Non-plastic when wet
2. Very slightly plastic when wet
3. Slightly plastic when wet
4. Moderately plastic when wet
5. Highly plastic when wet
6. Very highly plastic when wet

DRAINAGE INDEX KEY

1. Moraines or loose sand
2. Terraces - no illuviation
3. Rolling upland
4. Level upland
5. Low areas
6. Swampy areas with high water table
7. Water-logged areas

OXIDATION INDEX KEY

1. Red - brown
2. Yellowish brown
3. Brownish yellow
4. Yellow
5. Drab and yellow
6. Drab and blue
7. Blue

The compactness and plasticity keys were taken from the recommendations of J. C. Russell and committee (5). The drainage index is self-explanatory and was devised to describe conditions as they were encountered in the field. The oxidation index key is based on the color of the subsoil and is postulated on the theory that well oxidized soils are red or brown and reduced soils are drab to blue in color. The index key numbers corresponding to the soil condition of the site were assigned in each case and statistically correlated with tree growth as expressed by site index. (See Table 1.)

Compactness. Compactness is a function of texture, structure, moisture content, root penetration, and to a certain extent, chemical composition. Its manifestation in the field was exhibited in the degree of hardness experienced in digging a hole and the difficulty encountered in crushing lumps of soil in the hand. Compactness of the subsoil was found to be detrimental to the growth of black walnut and very greatly reduced the growth rate of black locust. It was observed also during the field work of this investigation that compaction of the surface soil by livestock invariably resulted in poorer growth both of locust and walnut. It is obvious that compaction of soil results in a reduction of the rate of aeration, without which mineral elements are not made available for the tree roots. A tight soil also prevents water absorption and penetration, and otherwise interferes with soil-water movement.

Plasticity in the subsoil generally is a measure of the extent to which a soil has been illuviated or drained. Estimation of this factor in the field was made on the basis of the ease with which the moist soil could be rolled into a wire or the difficulty experienced in moulding a lump of it in the hands.

Plasticity is an indication of soil colloid content. Up to a certain point colloids are beneficial to tree growth because they prevent excessive drainage and increase retention of soluble compounds, but beyond that amount they are often a growth deterrent because they decrease the rate of aeration, increase the percentage of rainfall run-off, and accentuate the difficulty of root development and penetration. When the field data on plasticity of the black locust subsoil were correlated with site index, it was found that heavy surface soil or heavy subsoil depressed growth of black locust. With black walnut the same was true of the surface soil, but the relationship was not definite for the subsoil.

TABLE 1

SAMPLE OF GROWTH AND SOIL DATA FROM BLACK LOCUST AND BLACK WALNUT PLOTS

| Plantation Plots | Site Index | Oxidation Index | Drainage Index | Plasticity Index | Compactness Index | Thickness A Hor. Inches | Thickness B Hor. Inches | pH A Horizon | pH B Horizon | Nitrogen-parts per million-A Hor. | Carbon-parts per million-A Hor. | Phosphorus per acre (2 million pounds) | Per cent Colloid A Horizon | Per cent Colloid B Horizon | Soil Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Plot No.) | | (Index Key No.) | | | | | | | | | | | | | |
| BLACK LOCUST | | | | | | | | | | | | | | | |
| *N.Y. 321 | 133 | 1 | 2 | 1 | 1 | 24 | 0 | 5.2 | | | | | | | Hudson sand |
| Ind. 255 | 117 | 2 | 2 | 4 | 3 | 48 | 0 | 7.0 | | 1720 | 16728 | 30 | 8 | | Genesee silt loam |
| Ind. 206 | 98 | 2 | 3 | 4 | 3 | 6 | 40 | 5.6 | 5.8 | 1500 | 9555 | 2.5 | 12 | 10 | Cincinnati silt loam |
| Ohio 72 | 95 | 3 | 3 | 4 | 4 | 6 | 39 | 5.9 | 5.3 | 2070 | 22386 | 8 | 17 | 23 | Wooster silt loam |
| Ind. 214 | 94 | 3 | 3 | 4 | 4 | 0 | 48 | | 5.3 | 1680 | 15288 | 6 | | 14 | Fairmount silty clay loam |
| Ohio 43 | 92 | 3 | 3 | 4 | 4 | 6 | 34 | 6.8 | 7.1 | 1550 | 17745 | 6 | 13 | 13 | Cincinnati silt loam |
| Ind. 217 | 92 | 2 | 3 | 5 | 6 | 5 | 67 | 5.3 | 5.7 | 850 | 10374 | 6 | 13 | 20 | Cincinnati silty clay loam |
| Ohio 18 | 54 | 3 | 3 | 4 | 5 | 6 | 24 | 7.2 | 7.6 | 2250 | 23593 | 20 | 16 | 11 | Miami clay loam |
| Ohio 134 | 52 | 2 | 3 | 4 | 5 | 7 | 21 | 5.6 | 6.0 | 1370 | 13377 | 15 | 14 | 19 | Muskingum silty clay loam |
| Ohio 7 | 50 | 4 | 4 | 5 | 6 | 4 | 14 | 6.3 | 6.6 | 2190 | 22932 | 20 | 15 | 22 | Rodman silty clay loam |
| Ohio 112 | 49 | 5 | 5 | 4 | 5 | 7 | 35 | 5.9 | 6.8 | 1800 | 15561 | 6 | 13 | 13 | Wabash clay loam |
| Ohio 159 | 38 | 6 | 6 | 6 | 7 | 0 | 28 | | 6.4 | 1140 | 10101 | 15 | | 13 | Abington silty clay loam |
| Ohio 164 | 38 | 5 | 5 | 5 | 5 | 8 | 16 | 6.2 | 6.6 | 1250 | 13650 | 10 | 14 | 15 | Crosby clay loam |
| **Tenn. 292 | 37 | 1 | 1 | 1 | 1 | 60 | 0 | 5.9 | | | | | | | Lexington sand |
| BLACK WALNUT | | | | | | | | | | | | | | | |
| Ind. 3 | 76 | 2 | 2 | 4 | 4 | 20 | 20 | 6.9 | 8.2 | 1440 | 15288 | 10 | 11 | 25 | Fox sandy clay loam |
| Ohio 28 | 71 | 2 | 2 | 2 | 3 | 20 | 0 | | | 1370 | 19110 | 100 | 9 | 12 | Bellfontaine sandy loam |
| Iowa 93 | 70 | 3 | 3 | 4 | 4 | 15 | 14 | 6.8 | 6.1 | 2740 | 33579 | 25 | 9 | 14 | Tama silty clay loam |
| Ind. 9 | 45 | 3 | 3 | 3 | 5 | 12 | 32 | 7.6 | 6.9 | 2610 | 17575 | 20 | 10 | 23 | Fincastle silt loam |
| Ohio 118 | 45 | 5 | 5 | 4 | 4 | 10 | 20 | 6.9 | | 3420 | 45318 | 90 | 21 | 27 | Brookston clay |

*Sandy soil with good moisture
**Sandy soil excessively drained

Plasticity Number. Forty samples of subsoil from the locust plots were selected for the determination of plasticity number. This measure of plasticity was determined in the laboratory and represents the difference between two moisture percentages: the upper, at which a soil will just flow, and the lower, at which it cannot be rolled into a 1/8-inch wire without crumbling. In this connection, it is probably an expression of colloid content projected into terms of soil compactness and drainage. Ten of these forty samples were selected from plots having the highest site indexes, ten from those of the lowest site indexes, and two groups of ten each from the plots of intermediate site indexes. The determinations, although showing a rather wide spread within each group, indicated an unmistakable relationship with site index closely paralleling the field estimate of plasticity. This test signifies that subsoils having a high plasticity number decrease growth rate for black locust. The test was not used for black walnut soils.

Drainage. Several factors were involved in assigning drainage index numbers to plots. Compactness, plasticity, aeration, and oxidation are very closely related to drainage, and it is difficult to consider one without the others. In recording the index of drainage, considerations of topography, nearness to drainage systems, soil texture and structure were given weight. The estimation of drainage, of course, overlaps that of other soil factors, but it gives an additional approach to site appraisal, and as such is valuable. Drainage was found to be highly significant in the case both of locust and walnut. Unsatisfactory growth invariably occurred on poorly drained soils.

Correlation of growth with the drainage index key encountered difficulties, however, in the case of excessively drained soils, because they also were poor sites for locust or walnut. A preliminary plotting of soil properties with site indexes showed that sands and thin soil over rock did not always follow the general trend of other plots. Some plots on sandy soil showed very high growth rates and some very low, even when most of the other soil properties were similar. Plots on thin soil over rock never showed as good growth as the soil properties themselves seemed to justify. This condition held true both for locust and walnut, and obviously was the result of excessive drainage. If the sand plot had a high water table or was located in a moist, sheltered cove or slope, the site index was usually very high; if the sand plot was on an excessively drained ridge, the growth rate was low. Specifically, the site index of the New York black locust plot 321 on Hudson sand was 133. (See Table 1.) This plot was on an alluvial fan at the foot of a gneiss ridge in the Hudson River Valley. The location favored optimum moisture conditions. Tennessee locust plot 292 on Lexington sand had a site index of 37, but the location was a dry, exposed slope with excessive underdrainage. Because sandy soil and shallow soil over rock introduced a variable which interfered seriously with correlation of other factors, it seemed advisable to segregate them in comparison with other plots.

Oxidation as Indicated by Color of Subsoil. It became apparent, as the investigation proceeded, that those soil properties which are conducive to drainage and aeration were in this region usually indicated by the subsoil color. The color of the subsoil generally is dependent on the state of oxidation, and this in turn is influenced by the extent to which the soil is aerated. A site with poor drainage because of heavy subsoil and a

high water table through a comparatively long period of the year has poor aeration. As a consequence, it is likely to be blue or drab in color because the oxides of iron remain in the ferrous condition. If the soil has good aeration the ferrous compounds are oxidized to red ferric oxides and the subsoil becomes red or brown. This change in color is the cumulative effect of years of aeration and not of short periods, although when exposed to the air the soil will change its color quite rapidly in some cases.

This relationship of subsoil color to growth was strikingly demonstrated by many plots. Frequently the subsoil varied within rather small distances in the same plantation, and commonly the more thriftily-growing trees were associated with a brown or reddish-brown subsoil, whereas the shorter, less thrifty trees were found on a blue, drab, or gray-mottled subsoil. Often there was no apparent difference on the surface unless one took into consideration a difference in level of a few inches or at most a foot or two. Little swales or depressions, however, often were indicative of a tighter and a more reduced subsoil where the trees had shallower root systems and less thrifty stems. The presence of a reddish brown or brown subsoil was very often associated with a coarse structure, although this was not always true. In some cases, soils high in clay content showed a good structure, perhaps because of good underdrainage. In general, however, good oxidation and porous structure were associated with good growth of locust and walnut, whereas poor oxidation and compact structure were associated with poor growth. Similar depressing effects of reduced soils on apple tree growth and productivity have been observed in New York and reported by Bradfield, Batjer, and Oskamp (1). Tight, poorly aerated subsoils were observed by Sweet (6) to depress apple tree growth in the Ozarks.

## Analysis And Discussion of Data on Chemical Soil Properties

When the problems of soil fertility and the relation of chemical properties to tree growth are considered on the basis of the data of this investigation, the results do not stand out significantly either for locust or walnut. Twenty-five soil samples were selected from the plots among the upper range of site indexes and twenty-five from the plots of poorest growth. Total nitrogen, organic carbon, phosphorus, and acidity (pH) were determined from these samples. There was little or no relationship shown between the amounts of the essential elements found in the soils of the plots examined and the growth of black locust or black walnut as indicated by site index.

Nitrogen - Black Locust. Six sample plots of excellent locust growth where meteorological influences could be assumed to be fairly constant (Indiana and Ohio Plots 255, 206, 214, 217, 72, and 43) were compared with six plots of much poorer growth (18, 134, 7, 112, 164, and 159) in the same region. The site indexes of the first set of plots ranged from 92 to 117, with an average of 98; those of the second set ranged from 38 to 54, with an average of 47. The pounds of nitrogen per million pounds of soil averaged 1562 for the plots of good growth and 1666 for those of poorer growth. The total pounds of nitrogen per acre in the upper twelve inches of soil were 3787 pounds for the first set of plots and 4305 pounds for the second set. The difference in the amounts of nitrogen could not be considered significant, yet the average site index of the first set of plots was more than twice that of the second set.

In any consideration of the relationship of the nitrogen content of soil to black locust growth, the fact that locust is a legume must be remembered. In this case either the nitrogen fixed must have been made available and quickly assimilated by the trees or else the minimum amount found as total nitrogen must have been above the limiting amount necessary for good growth. As a technical point this is important, but as a consideration in the choice of a locust planting site it is not. A soil relatively low in total nitrogen may still be a good site for locust.

When one considers the small amount of nitrogen necessary to produce a satisfactory growth of wood, the difficulty of securing correlation of growth with nitrogen content becomes evident. Those plots containing very large amounts of nitrogen would not contribute their influence in developing a high correlation coefficient because it is obvious that no amount of any element above that necessary to produce maximum growth would have any influence in showing growth increase. It is only within the range where nitrogen is limiting that one can hope to secure a high correlation figure with that variable. This investigation did not encounter such a condition within the plots studied.

Nitrogen - Black Walnut. The minimum amount of nitrogen per million pounds of soil found in the A horizon of walnut plots within the upper range of site indexes was 1370 pounds, or 6394 pounds per acre in the upper 12 inches. This particular plot (Ohio 28) had 10657 pounds total nitrogen per acre in its entire 20-inch A horizon. Such nitrogen content compares favorably with that in an average corn soil. These data might be interpreted to indicate that walnut needs a considerable amount of nitrogen for best growth, although they do not prove that walnut would not make good growth on a soil containing less nitrogen. However, in this rather extensive investigation no walnut plantation was found on a soil having less than 1000 pounds of nitrogen per million pounds of soil and the range in amount in the plots of good growth was very similar to that of the plots of poorest growth. Were data available for areas where planted walnut had failed and disappeared, more significant relationships might have been established.

Organic Carbon - Black Locust. It might be assumed, logically, that organic matter in the surface mineral soil would exert a great influence on locust growth, especially in the light of experience with agricultural crops, but a determination of organic carbon in the 50 above-mentioned samples disclosed no relationship with growth. In many instances the carbon content determined as organic carbon was a deep accumulation over long periods of time and the large amount did not exert an influence on growth in proportion to its magnitude. Specifically, in the case of a soil where there is an accumulation of organic matter to a depth of 8 to 20 inches, thoroughly disintegrated and diffused, the continuous water-holding capacity attributable to the organic matter may not be as great as in a soil where the accumulation of organic matter is much less, but where it is concentrated on the surface soil and in the immediate upper horizon. In the latter instance, the insulating effect against evaporation may be much greater than in the former, even though the actual amount of carbonaceous matter is less. In any event, the effect of organic carbon content was not commensurate with its amount.

Organic carbon - Black walnut. No significant correlation was observed between growth of black walnut and the amount of organic carbon in the surface horizons. Very wide variations occurred in the total amount of organic carbon in the upper 12 inches of the various sites. For instance, Ohio plot 28 and Iowa plot 93 contained 68,000 and 120,000 pounds of carbon, respectively, yet the site index for the former was 71 and for the latter 70. In the case of Indiana plot 9 and Ohio plot 118 the amounts were 64,000 and 163,000 pounds, respectively, and the site index of each was only 45.

The presence of data on prairie plots with soils high in organic carbon complicated the correlation. This soil was, of course, developed under conditions not indigenous to the natural habitat of black walnut. The presence of organic carbon in a forest soil is usually the result of favorable site conditions as regards temperature, exposure, and moisture evenly distributed during the growing season. Deep organic matter is usually found in the coves and sheltered spots in the woods and it was in such places that the best natural growth of walnut originally occurred. In the prairie soils the large amounts of organic matter were accumulated from grasses under conditions of rainfall unequally distributed over the year and in such a climate that grasses could survive better than trees.

Whether walnut will grow better on soil having a large amount of organic carbon cannot be determined on the basis of the data at hand. The fact that it was found naturally on soils well supplied with organic matter is indirect evidence that the species thrives under such conditions, but to say that the reason for its successful growth was carbon rather than some other element or factor would not be justified on the basis of this investigation.

Soluble Phosphorus - Locust and Walnut. The most that can be said concerning the relation of the soluble phosphorus content of the soil and the growth of black walnut or black locust is that even very small amounts of the element in the soluble form are no indication of low site quality. In other words, the amount of soluble phosphorus does not seem to have a significant relation to the growth of these two species. As little as 3 pounds of soluble phosphorus per acre was found on the better sites both of walnut and locust. Such an amount is extremely small as compared with that considered necessary for a good agricultural soil. Either this amount is not limiting or, as is more likely, a continuous supply of soluble phosphorus is made available as the growing season advances.

Soil Acidity by Quinhydrone Electrode - Locust and Walnut. Much research has been devoted to the effect of pH on legumes, and it has been accepted quite generally that soil acidity has an important influence on the growth of locust. The data of this investigation failed to show any correlation between pH and site index. In Table No. 2, the range of soil acidity has been given for groups of locust plots arranged according to site index classes. There is no significant difference between groups.

TABLE 2

| Site Index Range | Range of pH - Black Locust Plots | | |
|---|---|---|---|
| | A Horizon | B Horizon | C Horizon |
| 90-140 | 5.1 to 7.8 | 4.6 to 7.1 | 5.4 to 6.4 |
| 70-90 | 4.6 to 8.0 | 4.6 to 8.1 | 4.9 to 7.4 |
| 50-70 | 4.8 to 8.0 | 4.9 to 8.2 | 5.3 to 8.0 |
| 35-50 | 4.8 to 7.0 | 4.8 to 8.2 | 5.0 to 8.0 |

Summary of 246 Determinations

On the basis of these data, it may be said that within the range of 4.6 to 8.2 there is no apparent relationship between pH and locust growth.

An analysis of similar data secured on black walnut plots failed to show any correlation between pH and walnut growth. This was true of all horizons.

## SUMMARY

An investigation of physical and chemical soil properties as related to the growth of important tree species has been started at this Station with soil profile studies in 135 black locust and 120 black walnut plantation plots, to determine those properties which influence most significantly the growth of upland hardwoods.

From the data at hand it appears that the growth of locust and walnut is closely correlated with those properties of the subsoil - plasticity, compactness, and structure - which influence drainage and aeration. Both species appear to react very similarly and unfavorably to insufficient drainage or to excessive drainage.

This preliminary investigation has failed to show significant correlation between tree growth and degree of soil acidity or amount of chemical elements, either for locust or walnut. It is recognized that if data had been available for sites where plantations of these species had failed entirely, more significant results might have been obtained.

It is planned to extend the initial phase of this investigation summarized in this progress report by further studies of the behavior of these and other important tree species in planted and natural stands under the variety of site conditions found in the region, with supplemental fertilizer studies. For successful reforestation or forest management knowledge of the silvical characteristics of tree species is inadequate without equal knowledge of the sites on which they grow.

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# COMMENTS ON TIMBER STAND IMPROVEMENT IN THE CENTRAL STATES

Willis M. Baker, Director

With the initiation of emergency conservation work in the central hardwood region, the foresters of many organizations have been called upon suddenly to undertake extensive projects of timber stand improvement as a means of employing C.C.C. or relief labor, or to demonstrate to woodland owners some of the silvicultural measures of timber production. This has brought about a situation that should be called to the attention of those engaged in, or responsible for, this work.

Heretofore very little timber stand improvement has been attempted in the Central States except for a few instances in the farmwoods of the Corn Belt, where conditions are quite different from those encountered within the more heavily forested hill-sections of the unglaciated region to the south. Lack of funds and facilities for research has prevented or delayed studies of many of the silvicultural problems involved in the management of the forest types with which public agencies are now concerned. Consequently, much of the information essential to successful cultural operations is not available. Most of the foresters engaged in these new projects have necessarily been brought in from other regions, and, under the circumstances which exist, they have been forced to depend largely upon their experiences elsewhere, or upon the results of similar work in other sections of the country.

Even though many of the tree species encountered in the Central States are also found over most of the eastern states, it does not necessarily follow that they have the same relative value or that the same silvicultural methods will prove successful here. In fact, local conditions of site and climatic influences which become more critical as the prairie region is approached, inject into the silviculture of the central hardwoods many problems peculiarly local and often difficult of solution. To those foresters who may not appreciate this situation, a few suggestions based upon recent studies and observations may prove helpful, although it should be frankly stated and clearly realized that the available knowledge of stand improvement work in this region is woefully meager. Sound recommendations as to methods to use and results to be expected must await the outcome of research investigations, which in many instances have not yet been authorized or started. A discussion of some of the problems may arouse interest and lead to valuable observations from foresters working in the field of silvicultural management.

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Grazed Woods. On millions of woodland acres in the Central States timber stands have been depleted and growing sites have been deteriorated by continued grazing of livestock. This situation has become most serious in the farmwoods of the Corn Belt, but the harmful results of over-grazing are apparent throughout the central hardwood region. Better methods of land use, such as increased development of improved pastures following a reduction of cultivated crops on steep slopes or on easily eroded soils, may help to relieve excessive woods grazing in some sections (3).*

The typical severely grazed woods consists of an over-story of large trees and a more or less complete sod cover on the ground, with a conspicuous absence of an under-story of younger tree growth. A forester, unfamiliar with the problems presented by this condition and realizing the necessity for securing regeneration, might conclude that the overhead stand needed opening by the removal of overmature or inferior trees, especially those of undesirable species. Or, finding an abundance of recent seedling reproduction over the area, he might decide that a partial removal of overhead shade would aid them to develop. In both instances he would be following the worst possible procedure.

In the study of grazed woodlands in Indiana, conducted by the Station in cooperation with the Purdue Department of Forestry, Day and DenUyl (4) found that, in the more open woodlands with a complete sod cover, tree reproduction had the greatest difficulty in becoming established, or in growing satisfactorily after initial establishment. Frequently seedlings of various species start abundantly in the spring, appear promising during early summer, only to fail before the end of the growing season. Some of the more persistent may hang on for several years without making more than a few inches of height growth. Working on this same project, Diller (5) has described the adverse conditions of moisture and temperature which prevent or delay the regeneration of tree species on the compacted soils of woodlands opened up excessively by livestock browsing and trampling. Further cutting only aggravates the situation. Apparently the best stand improvement measure is merely to protect such woodlands in the hope that, after the elimination of live stock, sooner or later the combined influences of shade and undisturbed accumulations of leaf litter may gradually reduce the sod cover and restore forest soil conditions more favorable to hardwood reproduction. Not until this stage of restoration occurs should any cutting of trees be considered. Numerous attempts have been made to speed up this process by underplanting or interplanting with various species, but with very few exceptions these efforts have resulted in complete failure, chiefly because of the adverse site conditions created by years of over-grazing. It appears probable that site preparation by plowing or by some other method might aid materially in the establishment of planted or natural reproduction. Further investigations of these problems are obviously needed.

Old Field Stands. Throughout the poorer agricultural sections of the central hardwood region millions of acres of worn-out, abandoned farm lands are being reforested - some artificially with planted trees and others by natural reproduction. In localities where seed trees occur the native yellow pines, red cedar, and black locust encroach aggressively upon abandoned lands; but throughout the region sassafras, persimmon, and

*Numbers refer to literature cited, page 6.

other species of minor importance commercially are the ones which most commonly reoccupy old fields or pastures. Occasionally the more valuable hardwoods are able to reproduce, where seed has been available under conditions favorable for germination and establishment, but more often the better hardwoods come in later after forest conditions have been restored by a nurse-crop cover of sassafras or some other little-appreciated weed trees. These latter are a blessing in a disguise that many foresters apparently have been unable to penetrate, judging from the treatment to which the minor species are often subjected when a "stand improvement" job is attempted.

Unless or until there are enough trees of desirable species established to form the potential final crop and to benefit from weeding or liberation cutting, it is futile to attempt stand improvement work in young growth of the so-called weed species. In many old-field stands they usually predominate during their relatively short life-time, and the better species come in gradually as the nurse cover matures and thins out. A premature cutting only delays the final conversion, for the weed species invariably reproduce immediately and prolifically either from seeds or sprouts, or both. In stands where there are scattered trees of the desirable species, a limited amount of liberation cutting or thinning around each may be justified, but any attempt to eliminate the inferior species by cutting should be avoided, at least until we have learned if and how this conversion process may be aided.

It is likewise inadvisable to attempt an improvement cutting in an old-field stand, regardless of the composition of its species, if the trees have not thoroughly established forest conditions of ground litter and crown cover. Stand improvement work has been proposed, in some instances, for stands in which grasses, weeds, and other old field vegetation such as blackberry, crataegus, etc., have not yet been eliminated. It should be evident that forest restoration has not been completed, and to open up the stand further by premature cutting merely defeats or delays the process.

Upland Oak Types. Various species of oak, of which white oak is the most abundant and important, predominate in the more or less xerophytic associations of the oak-chestnut, oak-hickory, and oak-pine types that cover extensive areas of upland forest in the central hardwood region. Among the factors which contribute to the local occurrence and growth of tree species, one of the most important is soil moisture, and this in turn is dependent upon climate as well as upon soil formation and structure which influence the absorption, retention, and drainage of water. As the prairie region is approached, one would expect to find seasonal or periodic fluctuations in precipitation and frequent deficiencies in soil moisture tending to create conditions which only xerophytic species could endure. Chapman (2) has pointed out, in his study of natural forest associations, that site deterioration following clearing, livestock grazing, or burning, tends to prevent the reestablishment of species exacting in their soil and moisture requirements. The typical upland oak forest of today occurs on lands too poor to have been cleared for farming, or on lands which have reverted to woods following agricultural exhaustion. Excessive cutting, erosion, livestock grazing, or repeated fires have usually brought about more or less deterioration of site along with depletion of growing stock. The forester, in deciding upon measures of silvicultural treatment, must give due consideration to these facts.

Even under more favorable conditions it is doubtful if the upland oak forests on relatively dry sites are capable of producing satisfactory all-aged or two-story stands. The oaks and most of the associated species, such as hickory, ash, yellow poplar, etc., generally regarded as valuable, are relatively intolerant, and while their seedlings may start under considerable shade, they invariably grow little or not at all unless released promptly from all competition. Kuenzel's study (8) of chestnut oak reproduction in southern Indiana demonstrated the failure of oak seedling and sprout growth under the partial shade of a thinned stand. Similar results with white oak and other species have been observed repeatedly by the writer. Except under site conditions of fertility and moisture more favorable than those usually found in the upland oak types, the major species are not able to endure the competition encountered in the under-story of the forest.

On the other hand, most of the minor or less desirable species commonly found with oaks, such as dogwood, red maple, sassafras, black gum, ironwood, witchhazel, etc., are more tolerant and usually hang on persistently in the under-story. As a result, any slight opening of the overhead stand usually favors these undesirables, which immediately occupy the space to the exclusion of the more valuable species. This fact has been well brought out by Aughanbaugh (1) in his study of the establishment and growth of oak and associated species following the death of chestnut in Pennsylvania. He found seedling reproduction of both desirable and undesirable species in the openings vacated by the chestnut, but on the less favorable sites the better species invariably were being crowded out by the more rapid growth of the aggressive undesirables.

Under the conditions herein considered, stand improvement measures should be adopted with caution. In fully stocked young stands weedings, liberation cuttings, and thinnings may be undertaken in moderation to benefit potential final crop trees, but too heavy cuttings may introduce or encourage an under-story of tolerant undesirables which may prove very embarrassing to the forester at the time for final cutting. In older stands the best methods apparently are either to open the overhead crown very little by selection or improvement cuttings, so that the inferior under-story may be kept under control, or to provide large openings by heavy cuttings so that the better species may have ample opportunity, with the aid of liberation cutting as necessary, to reproduce and grow. From present knowledge it appears that the upland oak forests on relatively dry sites may be best adapted to management as even-aged stands. These may cover an entire area or they may be confined to selected groups just large enough to permit optimum development of the trees from seedling stage to maturity.

Oak Pine. Native yellow pines - shortleaf, Virginia, and pitch - are local associates of upland oaks on dry sites within the unglaciated sections of the region. Shortleaf pine is the most important and abundant of these species; extensive areas of the oak-shortleaf pine type are found in the Ozarks, and to a less extent in southern Ohio. Following settlement by the white man it is probable that the local distribution of yellow pines has been considerably extended, because of conditions favorable to their reproduction having been created by the abandonment of old fields, or by the opening up of the original hardwood stands through burning, grazing, or cutting. As forest sites deteriorate and become less favorable for hardwood reproduction, the less exacting pines find greater opportunity for development. For this reason Chapman (2) has advocated planting native pines on the poorer sites of the region. It would also appear logical to assume that,

if forest conditions favorable to hardwoods can be restored through protection and conservative management, the pines may be expected to find it increasingly difficult to maintain their present advances except on the poorer sites.

Many of the drier ridges and slopes of the Ohio Valley now occupied by scrubby, slow-growing oaks, or similar sites in the Ozarks on which post oak and blackjack oak now exist, would undoubtedly prove more productive if converted to stands of pine and oak. Such sites are at present incapable of supporting good hardwood stands. Where pine seed trees exist this may be accomplished by a partial or complete cutting of the oak at the time of a pine seed crop. If pine reproduction cannot be secured naturally it may prove advisable in some instances to plant pine in openings between oak stumps following clear-cutting.

Mesophytic Types. Mixed stands of various hardwood species, including many of those usually regarded as most valuable, are found throughout the Central States wherever local conditions of soil and moisture are favorable. Within the unglaciated hill country they are most common on fertile bottomlands along streams, in protected coves, or on moist lower slopes. Yellow poplar, white and red oak, hickory, ash, walnut, cherry, beech, maple, and elm are some of the species frequently found in mixture with others of equal or less value. Under the favorable conditions of site such stands are usually thrifty, grow vigorously, and are relatively free from serious damage from fire, insects, or disease. Of course this may not be true of abused or heavily culled stands, and Hepting (7) has reported serious defect in the extensive hardwoods of the Mississippi bottoms as a result of frequent fires.

From the standpoint of timber stand improvement the mixed hardwoods provide the forester with some of the most promising opportunities for cultural work, and at the same time the problems of silviculture encountered usually are less difficult than those presented by other forest types. Mixed hardwoods often occur as all-aged forests which respond favorably to selection cutting management. Where conditions for growth are optimum, even relatively intolerant species like yellow poplar and white oak are able to survive and overcome competition which they could not endure on less favorable sites. Seedling reproduction usually establishes promptly and grows vigorously as openings in the overhead stand are made; however, to secure regeneration of the species desired may require careful consideration of the time of cutting, and possibly subsequent weedings and liberation cuttings.

Most of the hardwoods also reproduce vigorously from sprouts, including the minor species of little value. In the management of all hardwood stands it is a question to what extent we should depend upon coppice regeneration. We need to know how to stimulate sprout growth where it may be desired, and how to control it where it is not wanted. Diller (6) has reported upon the results of cutting methods to reduce the sprouting of hophornbeam, but much more work of this kind is urgently needed. Problems of girdling and pruning also require investigation.

Conclusion. In this paper the writer has endeavored to point out only a few of the more obvious problems involved in silvicultural management of the central hardwoods, for the benefit of those foresters, now engaged in stand improvement projects, who may not have had an opportunity to become thoroughly familiar with forest conditions in this region.

It is realized that the discussion has been negative rather than positive; difficulties to be recognized and avoided where possible have been emphasized, but no attempt has been made to outline the procedure covering various phases of improvement cutting for the great variety of forest conditions that exist. This cannot be done on a sound basis of fact until a comprehensive program of research has yielded the necessary information.

This is the situation that must be faced by those who would undertake stand improvement work in this region at the present time. Persons responsible for projects must realize the difficulties to be overcome, and the probability of unfavorable public reaction to unsatisfactory results or failures. Projects which are admittedly experimental should be restricted to an experimental basis or scope. Good judgment certainly counsels us to proceed with caution until we learn more about the job attempted.

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# A BASIS FOR SELECTION OF SPECIES FOR REFORESTATION IN THE CENTRAL HARDWOOD REGION

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The task at hand of reforesting sub-marginal lands in the central hardwood region makes it imperative that all available information be enlisted to obtain the highest degree of success possible in the undertaking. The selection of species adapted to a region of varied climatic and site conditions is the chief problem needing immediate consideration. A better knowledge of methods of planting is also necessary, but may be acquired as the program progresses. The correct choice of species is fundamental. The ideal basis for planting projects would be a complete record of the responses of a sufficient number of sizable plantations of all the species, made on widely varied sites, which may be logically regarded as suited to the needs.

Plantation Survey. Unfortunately, this basis for appraisal does not exist within the central hardwood region, except possibly for a few hardwood species such as walnut and locust, which have been planted rather extensively throughout the Corn Belt. The recently expanded program of planting for erosion control, watershed protection, and restoration of forests on sub-marginal lands, has naturally been directed toward the unglaciated sections of rough hill-lands lying adjacent to and south of the Ohio and Missouri rivers. An investigational survey of all the established plantations that could be located within this region, made by the Station in 1934-35, disclosed the fact that they are inadequate to permit a conclusive determination of behavior and results. Approximately eighty-five per cent of all the plantings formerly made in the unglaciated portion of the region were found in the states of Ohio and Indiana. Of these, as well as of those of the other states, very few were old enough to yield much evidence of ultimate success, a large majority having been made within the past eight years. The distribution of plantations is neither wide enough nor uniform enough to test differences in behavior of species under various site conditions. Also, the extent to which exotics rather than native species have been planted has lessened the chances for evaluation of the latter in planted stands. In Missouri, very few plantings of any species have been established. Planting in northern Arkansas has been logically limited almost exclusively to shortleaf pine. In central and western Tennessee the two native pines, shortleaf and loblolly, and black locust have been most commonly used. On the favorable soils tulip poplar and other hardwoods have been planted to some extent.

When considering the reforestation of sub-marginal lands, usually with pronounced relief, the prime objective is to establish quickly a forest cover to retard erosion, to protect water-sheds, and to amend soil conditions. Another important objective is to establish a forest stand for timber production; on the better sites this objective may be the principal one. Planting for game cover, recreational values, type conversion, stand reënforcement, and

other purposes may receive varying degrees of attention. It was with the first two primary objectives in view that the survey was made.

Species which will fulfill the purposes set forth must possess certain rather specific qualifications, including ability to endure the "shock of transplanting" on sub-marginal lands; to grow satisfactorily and to produce a forest cover quickly; to form a good litter; to produce a canopy through which enough light may filter for the development of a vegetative ground cover and tree reproduction; to reproduce readily on sub-marginal lands; to produce low cost nursery seedlings; and to yield merchantable products. It is understood that the relative importance of these qualifications may vary with planting sites and with the purposes of planting.

Since present plantations of various species are neither numerous enough nor old enough to provide a sound basis for their evaluation in planting, it becomes necessary to depend upon a combination of records of existing plantations and observations of the distribution and behavior of native species. Accordingly the survey included a study of natural stands and old field regeneration, as an indication of what might be expected from plantations. A brief discussion of natural forest associations is pertinent at this point.

Native Forest Associations. The unglaciated region of the Central States has primarily a hardwood forest formation with its component associations. These range from extensive mixed mesophytic forests in the east to extensive oak forests with some hickory and pine in Arkansas and Missouri, interspersed with fingers of prairie vegetation.

The mixed mesophytic forest, comprised principally of beech, maple, yellow poplar, buckeye, black cherry, ash, chestnut, basswood, white and northern red oaks, is chiefly confined to the valleys of sharp relief. In general, these occur in parts of southeastern Ohio; in unglaciated southern Indiana and Illinois; in eastern Kentucky, including the "knobs" surrounding the "bluegrass"; in eastern Tennessee; and in the dissected loessial bluffs east of the Mississippi river in both Kentucky and Tennessee. Very limited areas also exist in Crowley's ridge in eastern Arkansas and in southeastern Missouri. The type develops best in coves and valley bottoms, and on protected slopes where there is a well aerated soil with a fairly constant supply of moisture and high relative humidity. In places somewhat more poorly drained, beech and maple may become the predominant species of the association.

Swamp forests of the region occur on stream bottom lands and poorly drained upland flats. These areas are largely agricultural and will seldom be classed as sub-marginal lands requiring planting.

When either clear or selective cutting is done in the mixed mesophytic forest, without subsequent cultivation or grazing, the same forest association often returns with the species possibly occurring in different relative percentages. However, near the tension zone between the mixed mesophytic forest and the oak-hickory or other types on the dry upper slopes, more often the more xeric species return. When cutover lands have been subjected to fires, grazing, cultivation, or to any combination of factors which destroys the forest ground

cover, litter, and soil structure, there results in most cases a development of a more xerophytic association of oak, oak-hickory, oak-pine, or pure pine.

Oak, oak-hickory, oak-chestnut, oak-pine, or pine types have occupied and still occupy the dry ridge tops and excessively drained upland flats. Following abandonment of cutover lands, the factors of the environment are such that only the most drought resistant oaks, hickories, and pines form the primary forest associations. These associations have been greatly extended in area at the expense of the more mesophytic ones since the early settlement operations of the white man in the region began during the latter part of the eighteenth century. This extension of types has been progressing more rapidly during the last half-century.

Of all the species occurring naturally in the region and used for planting, the southern yellow pines - shortleaf, pitch, and Virginia - appear to reproduce best on abandoned lands. Loblolly pine also occurs naturally in southern Tennessee, where it reproduces well. In southern Ohio the first three species are found in association, or singly in pure stands, or mixed with hardwoods. In Kentucky, all three species occur generally south and east of a line drawn through the western edge of the Cumberland Plateau; but west of the line only Virginia pine has been observed in any abundance. Virginia pine is distributed throughout the "knobs" region and in the western coal field about Dawson Springs. West of the Cumberland Plateau in Tennessee pine is limited to a few isolated areas of shortleaf and Virginia pines, principally in the region of the Tennessee river on outcrops of the Mississippian and Cretaceous formations, and to small areas of loblolly in McNairy County. Southern Indiana contains only Virginia pine in very local occurrence. In southern Illinois, shortleaf pine is confined to small stands in Union County, near Wolfe Lake, and in southern Randolph County. Likewise, only shortleaf pine occurs in southern Missouri and northern Arkansas. However, it occurs intermittently over extensive areas of the same geological formation. In the original forests, due to the prevalence of more tolerant hardwoods, the native southern yellow pines were largely confined to restricted areas on ridges and upper exposed slopes. After the opening up of the neighboring hardwood stands by settlers, pine reproduction occurred wherever seed was available or where trees were transplanted near buildings, explaining in part the isolation of many stands.

Certain soil factors have rather definitely limited most of the native conifers to given areas in the region. It may be observed that the distribution of pines, with the exception of Virginia pine, is almost universally confined to residual sandstone soils and cherty mantle, both materials being well drained and aerated. Eastern red cedar occurs on residual limestone soils, limestone outcrops, and residual soils derived from sandstones impregnated with calcium carbonate. It does not seem advisable at present to recommend planting of the native pines on tight, poorly-drained soils or soils with much available calcium, if good growth and reproduction are desired. Nor does it seem feasible that red cedar may be successfully established on heavy acid soils.

White pine grows in limited areas of the Central States. Isolated stands occur in protected places on sandstone soils in northeastern Iowa as far south as Muscatine, in Illinois as far south as LaSalle, and in Indiana as far south as Turkey Run State Park. In Ohio, still larger isolated stands of trees extend from Lake County, northeast of Cleveland, to Monroe County in the southeastern

part of the state. An extensive area in Kentucky, east of the "blue-grass," centering in Wolfe County and extending into the counties of Lee, Estill, and Menifee, contains native white pine in admixture with many species of mesic hardwoods in valleys and on protected slopes, and less frequently with pitch and shortleaf pines on drier sites. Locally, white pine often makes up a high percentage of the stand and is commercially important. In openings where forest soil and cover conditions have been not too greatly deteriorated, reproduction is common.

Other native northern conifers appearing in the Central States are hemlock, larch, and white cedar. Southern cypress occurs in swamps and river bottom lands as far north as southern Indiana; but, along with the northern conifers just mentioned, may be dismissed from serious consideration in a planting program that must deal largely with eroding, abandoned lands where frequent fluctuations of many site factors - primarily soil moisture, soil and air temperature, and relative humidity - are extreme.

Since most of the sub-marginal land of the central hardwood region lies within the transition zone between northern and southern forests as well as in the zone approaching prairie conditions from east to west, the difficulty of selection of species for planting is accentuated.

Conifers Versus Hardwoods. From observations made on the natural reproduction of primary forest associations on abandoned lands and in plantations in the unglaciated area, it has been well verified that the less exacting of the conifers become established more readily under adverse site conditions than do most hardwoods. On the deteriorated soils, early increment of these conifers greatly exceeds that of the hardwoods, with the possible exception of black locust. Upon these premises it is logical to confine planting on sub-marginal land largely to coniferous species.

As stated above, the forests of the region are primarily a hardwood formation. Markets have been established for hardwood species in the industries which are dependent upon them throughout the region. To attempt to change permanently the general physiognomy of the formation would be folly. To attempt to produce the softwoods to compete in the markets with regions already producing them would also be folly. It should be recognized that reforestation with conifers, therefore, is recommended as a means of hastening restoration of the hardwood forests through soil improvement and cover establishment. However, it may be desirable to introduce yellow pines for permanent management as oak-pine forest on the poorer, drier slopes of the region, which never were and never will be good hardwood sites. Particular reference is made to such areas as are found in the Ozark region of southern Missouri and northern Arkansas, where hardwood forests are composed mainly of the less valuable post, black, and blackjack oaks.

It will sometimes be feasible to do a limited amount of planting of hardwood species on good soils in the bottomlands and coves, and on protected slopes of the unglaciated region. Where such planting can be executed successfully, a number of stages in the succession of associations from the otherwise nurse crop of pines to the hardwood forest may be eliminated. This condition is also being brought about on many old fields by a natural nurse cover of sassafras and persimmon. Since the motive back of most hardwood plantings is production of valuable products such as may be obtained from black walnut, yellow poplar, white

and red oaks, relatively few species are being planted. These are all mesophytic species with tap roots which sustain much injury in the processes of seedling lifting and transplanting. Too often, failures have resulted in plantations on over-drained, exposed areas as a result of the limited root absorbing surface of the seedlings. Field seed spotting of the larger fruited species is being more widely practiced to eliminate the handling of seedlings.

The value of black locust for erosion control, for site improvement as a nurse crop cover, and for the production of fence posts is generally recognized, as is the susceptibility of this species to serious damage by the locust borer, especially on sites where growth is slow. Because of its good qualities and in spite of the danger of severe losses, black locust is being extensively planted for erosion control at the present time. On the lighter, better drained soils site improvement is often surprisingly rapid, and under many relatively young plantings in the region excellent reproduction of other hardwoods has become established. It is decidedly questionable if black locust planting should be continued at the present rate.

Native Conifers Versus Exotic Conifers. Final decision regarding the choice of indigenous or exotic species for forest planting in this region should be made only after due consideration has been given to the relative degrees of success of both in plantation. Although final success of any planting cannot be determined until maturity, growth characteristics and certain responses of planted species to their environment during the early years of establishment are criteria upon which certain evaluations may be based. At least, unpromising species for reforestation can be discarded.

In the northern states of this region such exotics as Norway spruce, Scots, Corsican, Austrian, jack* and Norway pines have been planted extensively. This general reliance upon exotics for reforestation is certainly traceable to the European influence upon early American forestry. The doubtful wisdom of this has been demonstrated repeatedly by failures due to unsatisfactory conditions for growth, and to their susceptibility to attack by insects and fungi. At present, the ratio of exotic stock to native stock produced for field planting is being decidedly lowered.

In establishing a forest cover by planting it is desirable to use species which at a later age will reproduce abundantly under highly fluctuating site factors; otherwise the task of replanting the area probably will recur after some unforeseen disaster or after harvesting the first crop. Observations made in the unglaciated areas of many twenty to thirty-year-old plantings and older isolated trees of exotic species, which are producing viable seed in abundance, revealed that reproduction has been limited to Scots and jack pines. Occasional seedlings of these species are establishing on protected areas only where there are good soil moisture conditions or where the soil approaches that under forest influences. The poor reproduction of planted exotics indicates strongly the futility of depending upon these species, either for the continuance of a forest cover until native species replace them through succession, or for the extension of a forest cover beyond the limits of plantations. The experience of nurserymen has shown that seedlings of northern evergreens in seedbeds are severely damaged in this region by exposure to long periods of direct sunlight accompanied by high temperatures at the soil surface.

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*Native American species, which are not indigenous to this region, are classed with exotics.

To insure a regeneration of our more desirable hardwood forests following planting of conifers, the site conditions must be altered to the extent that hardwood seeds will germinate and seedlings survive beneath the canopy. The exotics most commonly planted - Norway spruce, Scots, and Norway pines - produce dense foliage and canopies upon closing of the crowns. The shade is intensified under these stands, which usually show only slight differentiation of crown classes. This condition is especially true of the Norway pine. Beneath each of these in older plantings the ground is almost devoid of vegetation, either herbaceous or woody. Starvation of seedlings is probably one cause. The thick, slowly decomposing litter, which forms a poor seedbed, may be a further limiting factor. White pine is the only indigenous species used for planting which produces dense shade and heavy litter, equal to those of the exotics. Unlike the exotics, white pine develops excellent differentiation in crown classes. Shortleaf, pitch, and Virginia pines produce a thinner foliage; and in plantation as well as in natural stands, there is often a ground cover composed of herbaceous and shrubby species and reproduction of hardwoods and pines. The desirable two or three-story forest is thus developed.

The production of nursery stock of the exotics involves greater expense than that of the native pines. Generally, the planting stock of the exotics used in this region is three years old, seldom two, and often it is four years old. It is needless to enumerate the well known phases of nursery work which become costly in the time required to develop these transplants. In the northern states of the region, men who have planted shortleaf, pitch, and loblolly pines prefer 1-1 transplants. Farther south, where 1-0 seedlings are almost universally produced, the final cost of production is approximately one-fifth of that for the exotic species.

Recovery after damage by fire, grazing, and insects varies with species. None of the exotics considered here are known to sucker or sprout following severe injury by the agencies mentioned; but it is common knowledge that shortleaf and pitch pines develop new shoots from adventitious buds after damage, and that seedling sprouts often grow into well formed trees.

Although species most suitable for a quickly developing forest cover are of first consequence, especially for erosion control planting, attention should be given to the relative values of the final planted crops. The real commercial value of a species in any region does not depend wholly upon its wood characteristics, but also upon a certain scale of production which will supply the demands of regional wood-using industries. It does not seem advisable to introduce foreign species or native American species from regions far beyond the range of our central hardwoods and the associated pines in an attempt to create new local markets or compete with production of the exotics within their ranges, especially when we have so many valuable native species in the region.

Within the respective ranges of the native conifers - shortleaf, pitch, Virginia, loblolly, and white pines and eastern red cedar - the choice of species for planting should be based first upon consideration of their responses to site conditions, and second upon their commercial importance.

Until we can secure substantial data from mature stands of carefully planned experimental plantings, we are justified in making large scale plantings only on the basis of ecological principles applied to the native species of the region.

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Station Note
No. 28

February 27, 1936.

# COLLECTION, EXTRACTION, AND YIELD OF BLACK LOCUST SEED

By Leonard F. Kellogg, Silviculturist

Increased demand for nursery stock for erosion control planting has emphasized the need for and the value of good seed of black locust. Many forestry agencies can wisely and profitably collect their own seed supplies locally. Some are now following this procedure, with the advantage of obtaining seedling stock from known strains of locust adapted to and established in the locality. To aid them, available data on the collection, extraction, cleaning, and yield of black locust seed have been assembled.

Collection. In choosing trees from which to collect seed, search for those that are straight, healthy, thrifty, and rapidly growing. Weakened, poorly formed, and slowly growing trees may produce inferior seed. Endeavor to select seed trees at least ten years old and preferably older, since young trees probably do not produce as much seed of as high quality as do older trees. Last but not least, endeavor to collect large, well filled seed, since these produce superior seedlings. Where unusually good seed trees are found, they should be preserved if possible for future seed crops. Desirable qualities, such as early maturity of seed, complete and prompt germination, permeable seed coats, superior growth rates, and others, can be discovered only by careful, continual observations on seeds and seedlings of known parentage.

The ripened pods of black locust may be collected either from standing trees or from cuttings which are made after the seed has ripened. Hand picking often will be found to be a feasible method, especially where seed of exceptional quality has been located, although it will prove more expensive than collecting from cuttings, provided the latter are available. However, since there are so many black locust seeds in a pound (ranging from about 16,000 to 33,000 or more), the difference in cost of seed per thousand seedlings produced therefrom is not a very serious matter, provided that seed of a superior strain is obtained and treated to obtain high germination. First class seedlings from superior seed are well worth a slightly higher cost incurred in collection.

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In hand picking, if the tree is small one man can work alone from a ladder or by climbing. A sack hung across the shoulder by means of a piece of rope provides a convenient container for pods. On larger, more heavily yielding trees, an 8-foot pole tree pruner has proven very effective. The climber clips off small twigs bearing clusters of pods, which are gathered together later on the ground; or they can be collected simultaneously by a co-worker on the ground and clipped off with shears into sacks. The elimination of unnecessary twigs, sticks, and stems at the time of collection simplifies seed extraction later. Seed from the middle and upper portion of the tree crown is probably better than that from the lower limbs.

The output from hand picking varies according to the seed crop, size of trees, equipment used, ability of the pickers, and other factors. Over a period of several years collections have been made by Kellogg and Hall of this Station at the rate of from 1.5 to 3.2 pounds of pods per man hour. C. F. Olsen reports(1) collecting a truckload of locust pods in Mississippi at the rate of about 2.7 pounds per man hour, using colored labor. On the basis of these experiences, one man may be expected to hand pick from 12 to 25 pounds of pods in an 8-hour day, which should yield on the average from 3 to 6 pounds of seed.

Collecting pods from felled trees can be done more rapidly and at less cost. Ordinarily pods are picked directly into containers or sacks, although Hall used a somewhat different method in collecting seed from a 13-year-old locust plantation. As the trees were felled, pod-ladened limbs were cut off and the pods were flailed off with sticks over a 14 x 16 foot canvas stretched on level ground. This collection was made at the average rate of 6.3 pounds of pods per man hour. This method resulted in sticks and twigs being mixed with the pods, which interfered with the threshing operation; it was necessary to separate the trash from the pods at a cost of 3 cents per pound of seed.

In collecting seed from large roadside trees to be felled, a C.C.C. crew in southern Indiana used a block and tackle to lower the trees gently to prevent shattering of pods and loss of seed. The yield of seed was reported to be about four times greater than that from trees allowed to fall in the usual way with the attendant shock and jar.

Extraction. Seed of black locust may be extracted from pods either by an ordinary grain separator where quantity output is concerned, by a home-made thresher designed at this Station for smaller quantities of pods, or by hand flailing. Bean separators are less satisfactory, but they can be used if necessary.

Preliminary tests by this Station in 1933 indicated that an ordinary threshing separator is the best means of extracting seed on a large scale. Experience of many agencies has verified this opinion. The use of a Case

(1) Journal of Forestry, Vol. 32, No. 1, pp. 97-98.

separator was successfully demonstrated by C. F. Olsen of the Southern Forest Experiment Station, and D. A. Oliver similarly has used this method for extracting locust seed at the Parsons Nursery, Monongahela National Forest. State agencies have used the same means. A clover-huller attachment tried out in one instance did not work successfully in threshing locust pods; most of the seed was broken and ground up. Hall used a bean separator in threshing 3200 pounds of pods in 1934, with fair results. For large scale extraction a grain separator is the best and cheapest mechanical means available.

Breakage of seed may occur in threshing, but loss in this operation need not be tolerated. As much as 25 per cent of the seed has been broken in threshing small samples of pods in a small experimental separator. If a preliminary test run of the machine shows serious seed breakage, adjustment or removal of part of the machine's concaves should be made to correct the difficulty.

It is quite possible not only to thresh the locust pods, but also to clean the seed of foreign material in one operation. In Olsen's test, the seed was sufficiently cleaned that no further treatment was necessary. The best arrangement of screens in the machine was found to be a 1-inch lip screen on top, a 3/8-inch lip screen on the middle, and a 1/4-inch round hole screen on the bottom. The blower was half closed to prevent seed losses from excessive air draft. At the Parsons Nursery, Oliver found it necessary to clean the locust seed with a fanning mill after threshing. The screen arrangement used in his case is not known. Hall found it necessary to clean the pods of foreign material before his threshing operation in 1934. Apparently a competent thresher can combine or substitute his screens, adjust the concaves, adjust the blower draft, and regulate the speed of the machine so that threshing and cleaning can be done in one operation. The cost of seed can be reduced by attention to this detail.

Relatively few data are available on the cost of machine threshing. In Mississippi, Olsen found in threshing a truckload of locust pods in 1933 that the actual cost of labor and operation, but including no depreciation or supervision, was $0.0053 per bushel ($0.0012 per pound of seed). Oliver, in West Virginia, contracted for the threshing of 2,481 bushels of locust pods in 1933 for 2 cents per bushel ($0.008 per pound of seed). Hall's threshing operation in 1934 in Ohio, using a bean separator, cost $0.0275 per pound of seed.

A small, home-made thresher of black locust seed, designed at this Station[1] by B. F. Myer, is capable of threshing about 50 pounds of dry locust pods per hour, at an estimated cost of $0.04 per pound of seed. This machine permits the threshing of individual quantities of pods too small for a grain separator, and permits segregation of separate seed

(1) Station Note No. 27: "A Home-Made Thresher for Black Locust Seed Pods."

yields. At the same time, it is a far cheaper and faster method of extraction than flailing. After threshing, the seed is separated from pod chips and cleaned in a fanning mill.

The use of an old-fashioned flail for threshing black locust seed has proven effective for a small quantity of pods. A similar method consists of beating the pods in a tight grain sack with a club, working over and reworking the matrix of thoroughly dried pods and seed until all the seed is jarred loose. Since the volume of pods decreases as the beating progresses, it is necessary to tighten the string or add more pods to keep the matrix together. When all the seed is jarred loose, it can be separated from the pod chips in a fanning mill.

The cost of threshing locust seed by hand is considerably higher than by machine because of the time element. However, an excellent quality of work can be done by hand with little or no breakage of seed. Cleaning requires additional time.

Where it is necessary to clean the seed as a part of or following threshing, care in choosing the screens which are used will facilitate the cleaning operation. In the "Clipper" machine used for cleaning small quantities of seed at this Station, best results have been obtained with round-holed screens using on the top a #14 and on the bottom a #6 or #7, depending on the size of the seed. A #8 bottom screen may give better results when the seeds are unusually large.

Yield of Pods. Few data are available on yield of pods, especially for individual trees. The yield, of course, varies with the size of tree crown, and from year to year. In Ohio as much as 30 to 35 pounds of pods have been collected from single trees. In 1934, Hall recorded the amount of pods and seed produced on 18 acres of borer-damaged plantations which he clear cut in Ohio. The trees were spaced 10' x 10', and averaged 20 feet in height and 4 inches in diameter. The production of pods ranged from 152 to 209 pounds per acre and averaged 179 pounds; the yield of seed ranged from 22 to 31 pounds per acre and averaged 26 pounds.

Yield of Seed. The yield of black locust seed varies greatly with locality, seed year, size and thrift of parent tree, variety or strain, and probably other factors. One might expect yields of seed by machine threshing to be lower than those by hand methods; but the degree of filling of the pods, size of seed, and other factors appear to be of greater importance on yield than method of threshing, provided the seed is not broken in the process. In the following table, data on yields which have been obtained from the seed crops of 1933, 1934, and 1935 are summarized.

Some Yields of Seed from Black Locust Pods
Seed Crops of 1933, 1934, and 1935

| Source | Seed Locality | Seed Year | Quantity of Pods in Test | | Method of Extraction | Yield of Seed | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Total | Per bu. of Pods | Per 10 lbs. of Pods |
| | | | Lbs. | Bu. | | Lbs. | Lbs. | Lbs. |
| Olsen (1) | Miss. | 1933 | 12.8 | 1.2 | Hand | 3.6 | 3.00 | 2.81 |
| " | " | 1933 | 14.1 | 1.4 | " | 4.0 | 2.86 | 2.84 |
| Oliver(2) | Va. | 1933 | - | 13 | Separator | 65. | 5.00 | - |
| " | W.Va. | 1933 | - | 645. | " | 1736. | 2.69 | - |
| " | - | 1933 | - | 1823. | " | 4346. | 2.38 | - |
| Hall | Ohio | 1934 | 3364. | - | Bean Separator | 496. | - | 1.48 |
| " | " | 1934 | 5. | - | Hand | 1.35 | - | 2.70 |
| " | Ill. | 1934 | 79. | 8. | " | 23.2 | 2.90 | 2.94 |
| Kellogg | Ohio | 1933 | 15.6 | - | " | 3.5 | - | 2.24 |
| " | " | 1933 | 10.5 | - | " | 2.45 | - | 2.33 |
| " | Wis. | 1934 | 6.83 | - | " | 2.50 | - | 3.66 |
| " | Ohio | 1935 | 14.75 | - | Myer Thresher | 1.97 | - | 1.34 |
| " | " | 1935 | 10.25 | - | " " | 2.28 | - | 2.22 |
| " | " | 1935 | 12.25 | - | " " | 2.93 | - | 2.39 |
| " | " | 1935 | 11.0 | - | " " | 1.70 | - | 1.54 |
| " | " | 1935 | 72.0 | - | " " | 16.26 | - | 2.26 |
| " | " | 1935 | 31.5 | - | " " | 11.75 | - | 3.73 |
| " | " | 1935 | 31.5 | - | " " | 9.17 | - | 2.91 |
| " | " | 1935 | 21.5 | - | " " | 4.93 | - | 2.29 |

(1) Jour. of For., Vol. 32 (1): 97-98.
(2) At Parsons Nursery, W. Va.

The yields of seed in the above samples have been calculated and found to vary from 1.34 pounds to 3.73 pounds of seed per 10 pounds of dry pods. On a basis of volume, the yield varies from 2.38 pounds to 3.00 pounds of seed per bushel for the samples where volume was recorded, although one sample indicates a yield of 5 pounds of seed per bushel of pods. Weight is a preferable basis for calculation because of the differences in amounts of pods which can be packed into a bushel measure; yet moisture content is an important variable in calculations on a basis of weight.

All data at hand (including those in the Table) have been compiled to determine the average yield of seed to be expected. Most of these data are from southern Ohio, and apply to that locality. On a basis of 42 samples, the mean or average yield from 10 pounds of dry pods is 2.50 pounds with a standard deviation of $\pm$ 0.534 pounds. Olsen found that a 32-quart bushel of freshly threshed black locust seed weighed about 45.8 pounds. Hall found that a bushel of pods weighed about 9 to 10 pounds, and Olsen's tests at Holly Springs, Mississippi, indicate about the same, although in one case a bushel weighed only 5 pounds.

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U. S. Department of Agriculture - Forest Service
CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

Station Note
No. 27

February 25, 1936.

# A HOME-MADE THRESHER FOR BLACK LOCUST SEED PODS

By Ben F. Myer
E.C.W. Assistant

A convenient, inexpensive method is often needed to thresh seed from collections of black locust pods in quantities too small to justify the use of a grain thresher. Such a method is also useful to determine accurately the yield of seed of given trees or collections of pods, in experimentation. Losses of seed from breakage and from incomplete threshing have occurred in grain threshing machines, and, consequently, inaccurate data on yield of seed have been obtained from such machines. Furthermore, flailing of pods by hand is a slow, costly process.

The Central States Forest Experiment Station has developed a mechanical thresher which has facilitated greatly the handling of black locust seed pod collections and has given more complete threshing of seed. Much of the labor has been eliminated and the working time has been reduced to a fraction of that required by hand flailing methods. In the construction of this thresher, lumber and other materials on hand were utilized to reduce costs, as numerous changes were made during the process of development.

The black locust pod thresher consists essentially of a cylindrical drum (A in figure), which revolves in and rubs against the closed end of a U-shaped loop (B) of 1/4" mesh wire cloth. Tension on this loop is maintained by elastic bands (C). The open ends of the wire loop are fastened to the feeding end of the machine in such manner that an open space is provided through which the pods may be fed downward and against the drum revolving in the closed end of the wire loop. The abrasion of the drum against the wire cloth is increased by a series of fourteen cleats fitted longitudinally around its circumference at intervals of about four inches. The revolving drum is driven by a 1/4 H. P. electric motor (D), and is geared by pulleys to rotate at about 100 R.P.M. The action of the cleats, scraping the pods against and through the wire loop, reduces most of the material to a matrix which will pass through a 1/4" screen. Unthreshed pods work out at the sides of the loop. The matrix and the unthreshed pods drop to an inclined, oscillating false bottom (E) consisting of a frame, also covered with 1/4" wire cloth. The false bottom is pivoted at the lower end and is supported at the upper end by elastic bands (F). Oscillation is caused by two pairs of wooden eccentric blocks (G) attached to the rim of the cylinder. The oscillation of the wire cloth covering of the false bottom permits the ground matrix to pass through to a sacking hopper (H), and returns unground pods to a hopper (I) at the feeding point, to be placed again in the thresher. A wooden framework, lined with fly screen, houses the entire assembly and prevents the scattering of seeds and chaff.

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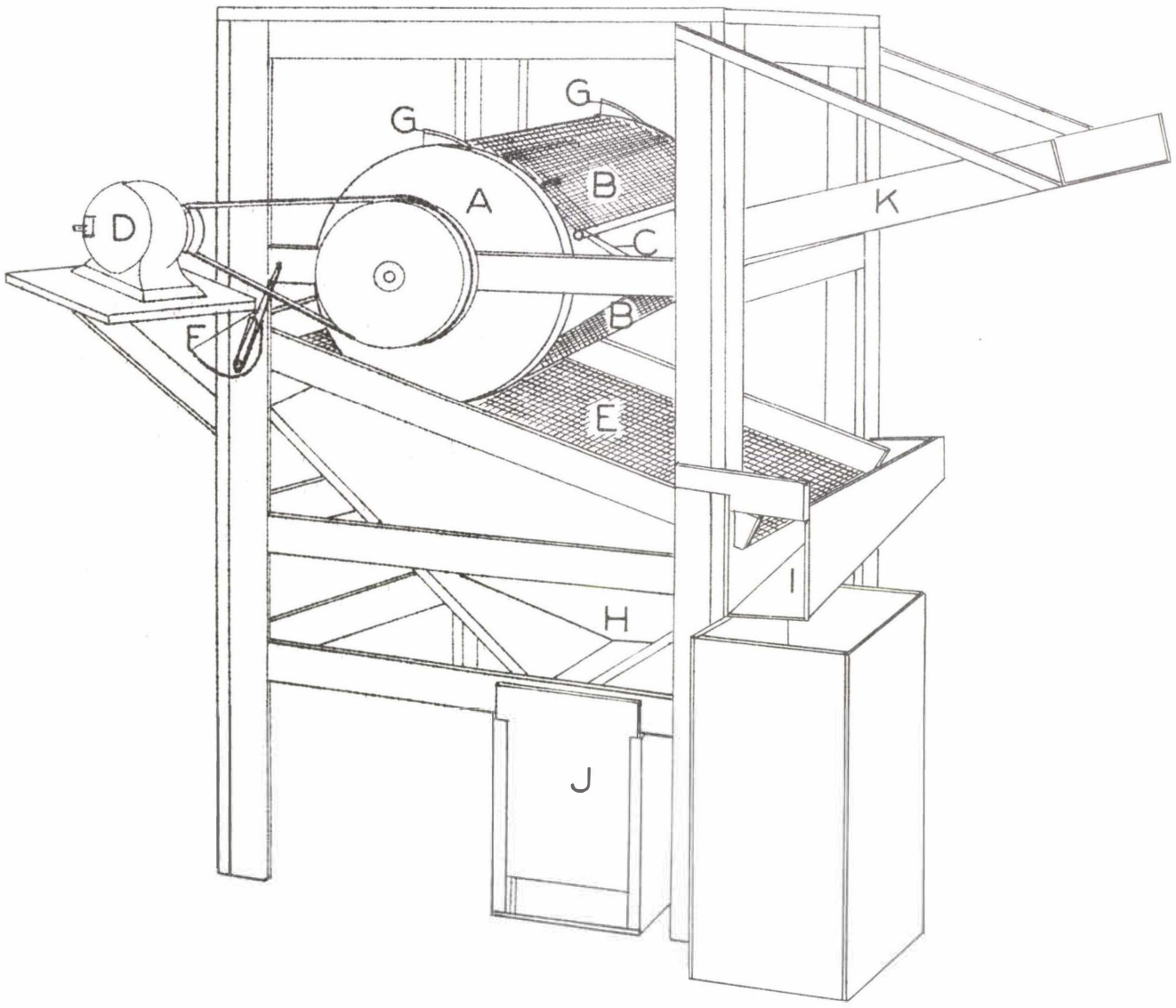
The amount of treatment necessary is dependent upon the condition of the pods. Thoroughly dried pods can be threshed by returning unground material to the machine only once. Pods which contain considerable moisture and collections containing large amounts of sticks and branches may require that returned material be run through the machine a second or third time. An inspection of the material returned by the false bottom is necessary to ascertain whether all seed has been separated from the pods.

An operator, feeding the machine and sacking the ground matrix, can thresh about six bushels, or fifty pounds, of pods per hour. The cost of threshing by machine is estimated to be about 4 cents per pound of seed, compared to 60 cents per pound of seed threshed by hand. These estimates are based on labor at 40 cents per hour.

In the construction of the thresher, a wide variety of choice in the selection of materials is presented. Angle iron and strap iron may be substituted for lumber in building the outside framework. The axle and drive shaft assembly of the revolving drum consists of iron pipe and fittings, seated in wooden bearings. The replacement of this material with steel shafting, seated in suitable bushing metal, would constitute considerable improvement. The feeding and sacking hoppers, which were made of fiber wallboard, would be more satisfactory if made of sheet metal or closely fitting lumber. Replacement of the elastic bands with spiral steel springs of the correct tension may be desirable. An electric motor of 1/2 H. P. or 1 H. P. would eliminate much of the attention necessary to feed the machine and prevent overloading.

The mixture of ground pods and seed as it comes from the thresher requires treatment in a fanning mill to separate and clean the seed. In some instances a second cleaning may be necessary to remove small stems and twigs.




## A HOME-MADE THRESHER FOR BLACK LOCUST SEED PODS

- A REVOLVING DRUM
- BB WIRE CLOTH LOOP
- C ELASTIC BANDS TO MAINTAIN TENSION ON LOOP
- D MOTOR
- E OSCILLATING FALSE BOTTOM
- F ELASTIC BANDS TO SUPPORT FALSE BOTTOM
- GG ECCENTRIC BLOCKS
- H HOPPER TO RECEIVE THRESHED MATRIX
- I HOPPER TO RECEIVE UNTHRESHED MATERIAL
- J HOPPER FOR COLLECTING THRESHED MATRIX
- K FEEDING HOPPER

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Station Note
No. 26

July 1, 1935.

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# A MODIFIED "AMES" TYPE OF SCARIFIER FOR BLACK LOCUST SEED

By A. G. Chapman, Associate Conservationist

The extensive planting of black locust in various parts of the country for erosion control requires the production of many millions of seedlings annually. Because a large proportion of black locust seed have impermeable seed coats which prevent or delay germination in the nursery beds, the recently increased use of this species has emphasized the importance of developing methods of seed treatment to obtain more prompt and complete germination.

Impermeability of Seed Coats. Germination and swelling tests of black locust seed collected in various parts of the Central States have revealed that from 15 to 90 per cent of the seed coats are impermeable to water, varying with different lots of seed (Table 1, Column 4). Seed which showed no swelling in water at room temperature within 10 days were considered to have impermeable seed coats, and actual seed bed tests demonstrated that there is a close relationship between swelling and germinative capacity. Impermeability was found to be due largely to suberized and cutinized secondary palisade cell walls, especially those at the outer ends of the cells adjacent to the outer or cuticularized layer. It is not definitely known why impermeability varies so widely among different lots of seed; but conditions of growth, degree of maturity of seed when gathered, methods of harvesting and storage, and inherent characters may be significant factors.

Chemical Treatment. Various chemical or soaking treatments have been suggested for reducing the impermeability of black locust seed coats, some of which have been used with considerable success. However, any chemical method involves wetting the seed and creates danger of injury to the embryos through the processes of swelling and subsequent drying, by mechanical injury from handling in a swollen or softened condition, by exposure of the embryos of seeds having naturally permeable coats, and by over-exposure of the seed to the chemical. After treatment, careful drying and storage before sowing are essential to prevent further loss.

Mechanical Treatment. In the belief that mechanical treatment of black locust seed might prove cheaper, safer, and more satisfactory in many instances where large quantities of seed are to be sown, methods of scarification of the seed coats to reduce their impermeability have been studied at the Central States Forest Experiment Station.

Use of the "barrel" type of seed scarifier has been suggested, but it does not effectively scarify lots of "hard coated" seed, and it is not adapted to rapid treatment of seed in large quantities. The various types of machines designed to scarify seed of sweet clover and other legumes were found to damage black locust seed severely through breakage, often grinding them into meal. Further tests

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indicated that the "Ames" type of seed scarifier is readily adapted to modifications in design to permit of its use for effective and economical treatment of black locust seed. The work that has been done to date and the results achieved are explained herein for the benefit of nurserymen who need this or similar equipment immediately. Further experimentation will undoubtedly lead to an even more efficient scarifying machine.

The "Ames" Scarifier. The Ames hulling and scarifying machine was developed about 1913 by Professor H. D. Hughes of the Farm Crops Department, Iowa State College, Ames, Iowa, for use on sweet clover seed. Its principle is simple and has been used as the basis for other types of scarifying machines. Before any changes were made, the "Ames" scarifier damaged black locust seed severely through breakage, but its simple construction permitted of modifications to correct this and other difficulties (Figure 1). The principal changes were a control of the fan speed; a closing of the side fan-openings with screen to prevent loss of seed; a reduction of the cross-section of the seed race (originally 2 inches by 10 inches) to approach more nearly that of the blower pipe; and the covering of both broad inner faces of the race with an abrasive.

A "forge blower" with a 12-inch fan is mounted on a platform near an A. C., single phase, one horse-power, electric motor with a 1750 R.P.M. for currents of 110-220 volts. Both the motor and fan are equipped with a set of "three-speed intermediate pulleys" arranged for varying the fan speed with one length of belt (Figure 1-C). The fan originally had four blades; but at the time of purchase, it was equipped with four additional blades. To the end of each, a broader blade of heavy galvanized sheeting with forward projecting flanges had been riveted. A 2-inch rim of the same metal had been cut and riveted to these flanges on either side of the fan. This made it possible to add the four extra blades (short ones), one midway between two original blades, to produce a greater air current and to give a more uniform blasting of seed against the abrasive surfaces of the race (Figure 1-B). The blower fan rotates in a cast iron housing which has a 4-inch opening on either side. With the exception of a small space for the seed spout, these openings were closed by fastening galvanized hardware cloth over them with screws to prevent loss of seed flung by the fan. A semi-circular tight race with an inner cross-section of 2 inches by $5\frac{1}{2}$ inches is attached at the lower end to the blower. Before the reduction in the cross-section had been made, the air current was insufficient to carry the heavy black locust seed through the machine. Both of the broad inner faces of the race are surfaced with strips of #3 or #$3\frac{1}{2}$ Garnet Paper. This paper, 6 or 8 inches wide, may be purchased in rolls. By surfacing both of the broad inner faces of the seed race, scarification was considerably increased. Directly above the blower is a hopper from which seed is fed into the race through the fan at a rate controlled by a slide. The seed is scarified by being blasted against the curved surfaces of the race by the fan blades and the air current and is carried into a hopper at the rear of the machine from which it can be sacked.

Seed pass through a series of baffle plates at the end of the race before entering the second hopper. The plates are designed to clean the seed of light chaff which passes out of the machine with the air current while the heavier seed are checked and drop into the hopper. However, most seed now on the market are well cleaned.

The speed of the fan, controlled by the pulleys used, should be varied between 1700 and 2200 R.P.M. for different lots of seed. Usually, the larger the

seed, the greater are the ease of scarifying and the damage through breakage. Also, seed coats vary widely in their brittleness. The optimum speed may be determined on 1/4 pound of seed. This speed is the maximum which the coats can withstand with a minimum of breakage. Exceptionally tough coated seed will require the maximum speed and may withstand a second treatment if necessary. Breakage is easily held to less than 2 per cent by proper control of the fan speed.

The cost of the machine is relatively low. Although the Ames scarifier is no longer on the market, used outfits (for remodeling), excluding the motor, may be purchased for fifteen to twenty-five dollars from county Farm Bureau agencies, High School departments of agriculture, or from other agencies or individuals who have discarded them for more modern equipment; or one may be easily constructed. Costs involve those for new or used forge blower and electric motor, lumber for frame work, 28-gauge or heavier galvanized sheeting for hoppers and seed race, and Garnet Paper. When this investment is pro-rated over a period of years, and when large quantities of locust seed are treated, the cost of scarification is low.

The rate at which seed can be scarified with this machine encourages more general treatment of seed in one-half ton or greater lots prior to sowing. Although size of seed and brittleness of seed coats may vary the rate somewhat, a bushel of seed can be scarified in approximately 5 minutes.

Results of Scarification. Tests on numerous lots of seed have shown that the percentage of germination of scarified seed is appreciably increased. The table below gives the per cent of swelling (approximate germinative capacity) for each of 10 lots of untreated and scarified seed. Samples of 250 seed of each were soaked in water for a period of 10 days. The treated seed was scarified at a fan speed of 2000 R.P.M.

Table 1

| Seed Source | Seed per pound | Loss by breakage at 2000 R.P.M. | Swelling Test | | Increase in swelling due to Scarification |
|---|---|---|---|---|---|
| | | | Untreated Seed | Whole Scarified Seed | |
| | Number | Approximate Per cent | Per cent | Per cent | Per cent |
| 1. Aurora, Ind. | 24,480 | 0.1 | 11.5 | 89.0 | 77.1 |
| 2. Hillsboro, Ohio | 16,329 | 5.0 | 87.4 | 99.2 | 11.8 |
| 3. Butler, Ohio | 28,896 | 1.5 | 31.3 | 93.1 | 61.8 |
| 4. Minerva, Ohio | 23,274 | 3.0 | 21.8 | 95.0 | 73.2 |
| 5. Milton, Ky. | 26,284 | 1.5 | 47.8 | 97.1 | 49.3 |
| 6. Peekskill, N. Y. | 20,160 | 3.0 | 24.0 | 98.1 | 74.1 |
| 7. Elizabethtown, Ill. | 24,210 | 0.5 | 25.0 | 94.3 | 69.3 |
| 8. Southern Europe | 21,420 | 0.5 | 50.6 | 91.2 | 40.6 |
| 9. Cottage Grove, Tenn. | 18,450 | 2.5 | 32.4 | 90.7 | 58.3 |
| 10. Unknown (Katzenstein) | 24,570 | 0.1 | 39.3 | 95.0 | 55.7 |

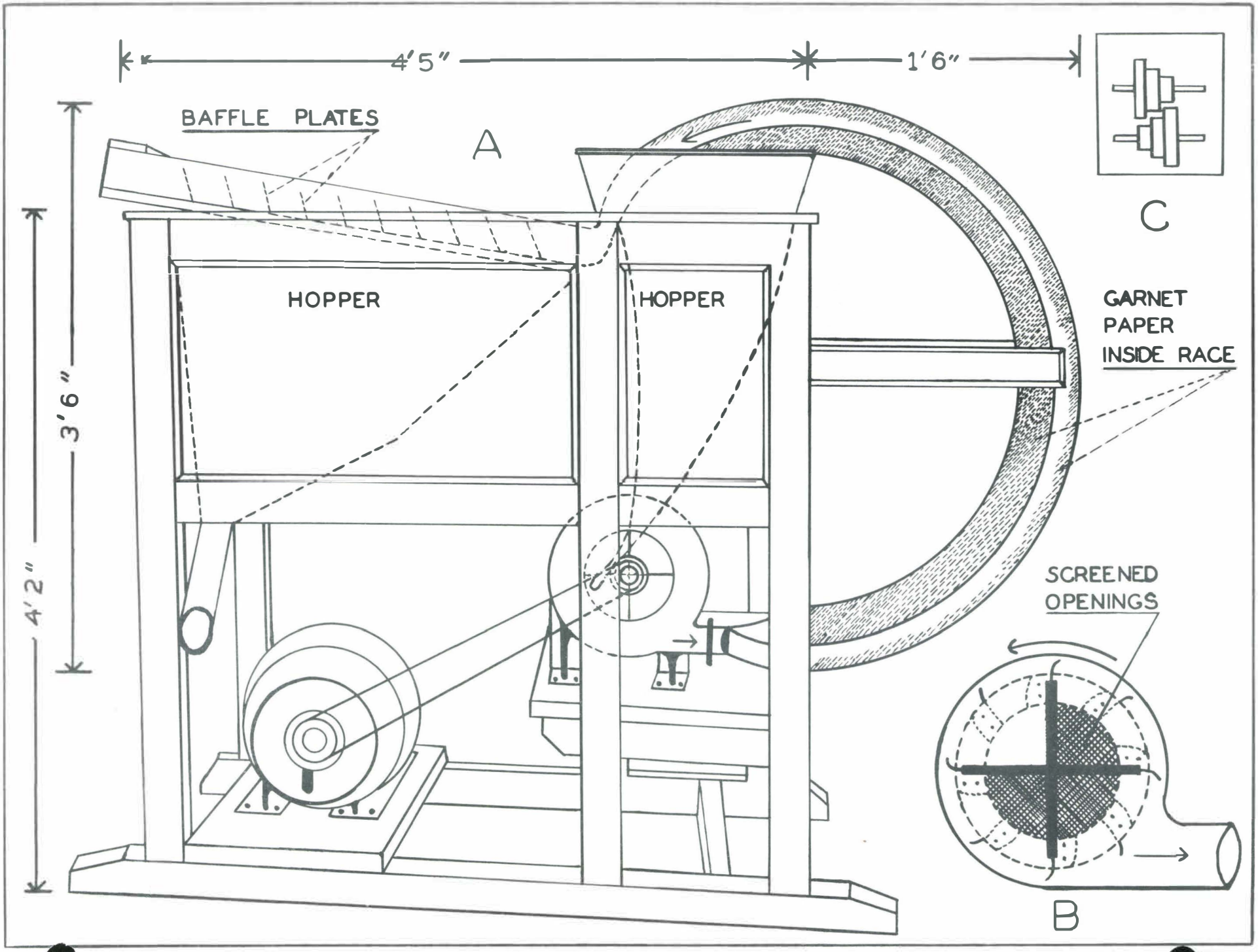
4'5"
1'6"
BAFFLE PLATES
A
C
HOPPER
HOPPER
GARNET
PAPER
INSIDE RACE
3'6"
4'2"
SCREENED
OPENINGS
B

FIGURE 1

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Station Note
No. 25

June 10, 1935.

# THE RELATION OF STUMP HEIGHT TO THE SPROUTING OF HOP HORNBEAM IN NORTHERN INDIANA

By O. D. Diller, Assistant Conservationist

In the management of hardwood stands the control of sprouting is of major importance. This may involve the encouragement of sprouting in certain species and its suppression in others. In weeding, cleaning, or thinning young stands, or in the work of stand improvement now being undertaken on a large scale by C.C.C. labor, a knowledge of the sprouting capacity of the various tree species is very desirable and important.

Sprouting ability differs greatly with species. Some species sprout vigorously under a variety of conditions, others only under very favorable circumstances. Certain trees sprout from the roots, others only from the main stem. In some species adventitious buds are most important in the origin of sprouts, while in others dormant buds play a leading role. The literature on the subject of sprouting is neither abundant nor conclusive. Scarcely enough data have been collected on the various species to classify trees in the order of their sprouting ability. It is obvious, therefore, that additional data on the behavior of individual species under various conditions are necessary.

Little is known regarding the relation of height of stumps to the number and vitality of the sprouts which they may support. That this depends very largely on the species under consideration, has been brought out by a cutting experiment carried on in northern Indiana during the last two seasons. The Station's first effort in its sprouting investigation was started in a small way by a study of hop hornbeam (Ostrya virginiana) (Mill.) K. Koch. This species is undoubtedly the most important weed tree in the farm woodlands of the Corn Belt. In many areas it dominates the understory so completely that the reproduction of the more valuable trees is often suppressed or prevented from becoming established. As many as 2,500 stems per acre of hornbeams under three inches in diameter have been found in a number of unmanaged farmwoods. Obviously then, any method of cutting which tends to discourage sprout formation is desirable, and it was with this purpose in mind that this experiment was undertaken.

Methods. This study has been carried on in three locations in northern Indiana. On August 6, 1933, a total of 833 hop hornbeam saplings were cut* in a beech-maple woodland in Grant County. The trees were cut at nine different stump heights, starting with stumps at the ground surface and increasing the height at six-inch intervals up to four feet above the ground. One month later in the same woodland the experiment was

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* The field work was done with the assistance of Mr. E. D. Marshall, formerly Field Assistant, Purdue Agricultural Experiment Station.

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repeated with 919 trees. Also during this month, in a beech-maple woodland in DeKalb County, 764 trees were removed, all of which were cut at the ground level, making a total of 1,683 trees cut in September, 1933. On July 10, 1934, two additional plots were established in an oak-hickory woodland in Cass County, in which 165 trees were cut at the ground level and 100 trees cut at a six-inch stump height. A scissors type of pruner was used in cutting the saplings, which ranged from 0.5 to 2.5 inches in diameter.

Results. The first remeasurements were made in July, 1934, and during the latter part of May, 1935, all the plots were again remeasured. The results obtained from the July, August, and September cuttings were very similar and, therefore, all the data are summarized in one graph and table. These show a very striking relationship between the number of trees killed and the height at which they were cut. For example, it can be seen that approximately 83% of the trees which were cut at the ground surface failed to sprout, in contrast to less than 10% at the 24-inch stump height.

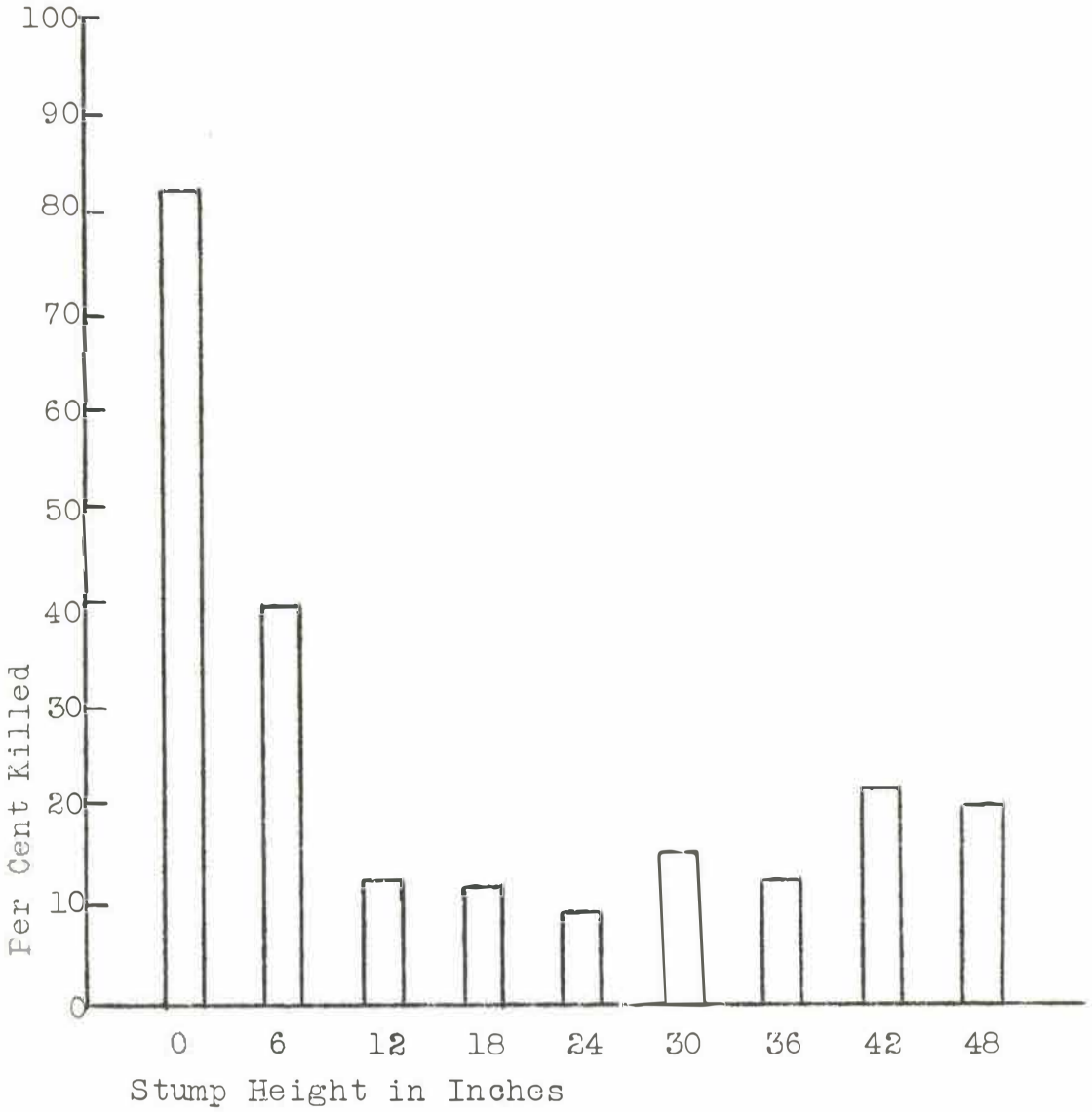
The reason for the 83% effective kill which resulted when the trees were cut at the ground surface is probably due to the fact that the sprouts originated only from the main stems and not from the roots. This is apparently the reason why the trees cut at the ground surface showed much less sprouting than the trees cut at higher stump heights. The slight increase in mortality obtained at heights above 24 inches is difficult to explain. It is probably due to some little understood phenomenon of apical dominance, polarity, or equilibrium of some sort between the top and roots.

It is commonly believed that the sprouts of most tree species come from adventitious buds. In the case of hop hornbeam, however, it was possible to trace the pith of all the sprouts examined to the center of the main stem. This indicates that these sprouts came from dormant axillary buds which remained alive from one year to the next and became active when that part of the shoot above them was removed. Most of the trees which were cut were between the ages of 10 and 20 years and were less than 2.5 inches in diameter. Whether this type of bud is responsible for sprouts which come from hop hornbeams larger than 2.5 inches in diameter has not been investigated.

Although the data obtained to date in northern Indiana were secured during two consecutive dry seasons, it appears that the best height at which to cut hop hornbeam in this section is at the ground surface. The few larger trees which were girdled at varying heights gave similar results and indicated that the best height at which to girdle the larger trees is also at the ground surface.

Besides the specific anatomical properties which influence sprouting capacity, it is realized that a number of interrelating factors, such as climate, soil conditions, age and condition of tree, and time of cutting, are involved in this problem. Before any general conclusions can be drawn, therefore, it is necessary that intensive studies be made on individual species over a wide range of conditions.

The Relation of the Per Cent of Trees Killed to Stump Height of Hop Hornbeam




| Stump Height | Trees Cut | Trees which Failed to Sprout | |
|---|---|---|---|
| Inches | Number | Number | Per Cent |
| 0 | 1,110 | 917 | 82.6 |
| 6 | 311 | 126 | 40.5 |
| 12 | 165 | 21 | 12.7 |
| 18 | 195 | 23 | 11.8 |
| 24 | 260 | 25 | 9.6 |
| 30 | 195 | 29 | 14.9 |
| 36 | 192 | 24 | 12.5 |
| 42 | 172 | 37 | 21.5 |
| 48 | 181 | 36 | 19.9 |

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Station Note
No. 24

June 1, 1935.

# THE EFFECT OF WOODLAND GRAZING ON CERTAIN SITE FACTORS IN THE OAK-HICKORY TYPE

By Oliver D. Diller, Technician

The almost universal practice of woods grazing in the better agricultural sections of the Central States is quite generally recognized as the major cause of the continued deterioration of the farmwoods in these sections. In certain limited areas they are faced with almost total extinction if present grazing practices are continued. Fully fifty per cent of the farmwoods in the Corn Belt are no longer capable of yielding valuable forest products, nor are they of any great value for the production of forage. Although this situation is acute, as yet there has been insufficient research on the basic economic and silvicultural relationships of grazing to the farmwoods. Such a comprehensive study has been started on a cooperative basis between the Central States Forest Experiment Station and the Purdue Agricultural Experiment Station.

Periodic remeasurements of permanent sample plots established in connection with this study have demonstrated that natural reproduction cannot be secured without complete protection from grazing. Plots located in woodlands from which livestock have been removed for periods of from one to twenty-five years indicate that where such areas have not passed beyond a certain stage of decadence they are capable of natural recovery to a productive forest condition. Other woodlands which have deteriorated to the point where a complete sod cover had become established were found to be incapable of natural recovery within a reasonable length of time.

The data available from a study of permanent sample plots were insufficient to establish the causal relationships involved. A more intensive ecological study was made by the writer* during the summers of 1932 and 1933 to determine the effect of excessive grazing on certain environmental or site factors, and to ascertain under what conditions they become limiting in the germination, survival, and establishment of natural tree reproduction. These intensive site studies were carried on in quadrats, 2-mil-acres in area, which were located in a number of northern Indiana farmwoods representing the various stages of grazing. Observations and periodic measurements made in these quadrats served to establish some significant relationships, which are herein briefly summarized. Since woodland grazing is the most severe in the better agricultural areas of the Corn Belt, it was assumed that mineral elements of the soil did not constitute limiting factors, and, therefore, no studies of this nature were undertaken. It is hoped that this project may be continued through several more seasons because these data were collected during a severe drought period, which may have influenced the results obtained.

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* This investigation was made possible by cooperation between the Department of Botany, Ohio State University; the Central States Forest Experiment Station; and the Department of Forestry, Purdue Agricultural Experiment Station.

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Soil Moisture. Periodic moisture determinations were made in quadrats representative of varying degrees of decadence and subsequent recovery from previous grazing. These studies indicate that soil moisture is one of the most important limiting factors in establishment of natural reproduction. Red oak seedlings, for example, did not survive a moisture content of 4.7%, or 22.7% of the moisture equivalent. In the more advanced stages of decadence, where the stands have been opened up to the extent that the soil is subjected to excessive evaporation, the moisture content in the upper 10 inches of soil reached or fell below this critical point early in the growing season. A low of 3.8% moisture content, or 17.9% of the moisture equivalent, was recorded on July 25, 1933.

This soil moisture relationship explains, in part at least, one of the most perplexing problems in the natural regeneration of grazed farm woodlands. It has been frequently observed that many woodlands contain an apparently promising stand of reproduction during the late spring and early summer months, but by mid-summer the seedlings almost entirely disappeared. Repeated observations on the same area have indicated that this may happen year after year, with no material survival from one year to the next. It seems probable that the woodlands which have been partially opened up through continuous grazing, and have a complete sod cover established, suffer greater loss of soil moisture than in any other stage of decadence. This will be discussed at greater length in the last paragraph of this paper.

Soil Porosity and Water Absorption. Continued overgrazing has a deteriorating effect on the physical condition of the soil. It produces a hard, compacted, and poorly aerated surface horizon, incapable of high moisture absorption, and, in general, of such low tilth as to provide very unfavorable conditions for germination and establishment of tree seedlings. Auten (1) found that the weight of samples from the upper nine inches of soil in grazed woods averaged 15 per cent heavier than corresponding soil sections in ungrazed woods. Similar studies made by the writer in previously grazed woodlands from which the cattle had been removed for varying periods, indicate that with protection these soil conditions gradually become more favorable for regeneration. The average weight of soil samples taken from the upper 3 inch layer of soil in woods protected from grazing for more than ten years was 15 per cent lighter than similar samples taken from woods from which cattle had been only recently removed. A series of water absorption tests further demonstrated this gradual improvement of environmental conditions. It was found that after 10 years of protection the surface soil absorbed water more than 7½ times as rapidly as the surface soil of woodlands which were being grazed at the time the tests were made.

Leaf Litter. Too much emphasis cannot be placed on the importance of a leaf litter cover in producing an environment most suitable for the germination and survival of the heavier seeded tree species. The outstanding influence of leaf litter is to conserve moisture, to act as an insulator against climatic extremes, to return certain mineral elements to the soil, and to retain soil porosity. Grazing inhibits the accumulation of leaf litter through trampling the litter into the mineral soil where decomposition takes place very rapidly. Disintegration of litter is also hastened

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(1) Auten, John T. - Porosity and Water Absorption of Forest Soils. Journal Agr. Res. Vol. 46, No. 11, Washington, D. C. June, 1933. Summarized as Station Note No. 8.

by the increased desiccating action of both wind and sun which accompanies the opening up of the stand. This increased wind action also results in erratic distribution of leaf litter. In the more open woods the litter accumulates against the leeward fence or is blown entirely out of the woods.

The Influence of Light. Under favorable forest conditions, foresters consider light as one of the most important factors necessary in successful natural regeneration, and, therefore, it is seldom regarded as inhibiting in its effects. In the open farmwoods of the Corn Belt, however, where prairie conditions are approached, it appears that too much light reaching the ground may have certain harmful effects, especially on very young seedlings. It appears that this unfavorable effect of direct sunlight becomes important through its interrelated effects on soil temperature, relative humidity, evaporation, transpiration, soil moisture, and the formation of a sod cover.

Hourly fluctuations in radiation were found to be of as great importance as the total radiation throughout the day. The light intensity determinations indicate that optimum conditions are found for survival of red oak seedlings where the intensity at the ground does not exceed 46 per cent of the intensity in the open at any time of the day. Light intensity measurements taken on quadrats where the seedlings were in an unhealthy condition were found to average over 50 per cent of the intensity in the open during the noon hours, and reached a maximum of 65 per cent. Quadrats where most of the reproduction had died were exposed to full sunlight during the greater part of the day.

These data support the earlier conclusions of Day and DenUyl (2) that the density of the overhead stand is one of the two principal factors controlling the germination, establishment, survival, and growth of reproduction in the grazed farmwoods. It is evident that as the crown canopy becomes more open a greater amount of solar radiation reaches the ground, which adversely influences the environmental conditions by raising the soil and air temperatures, lowering the relative humidity and soil moisture, and increasing evaporation and transpiration.

Temperature. The average maximum soil temperature at a depth of two inches was found to be higher on those quadrats where most of the seedlings had died, and also on those quadrats where they were unhealthy, than on quadrats where the reproduction was in a healthy condition. The respective readings were 82.7°, 74.4°, and 71.0°F. Whether these figures are significant remains to be determined. While it seems improbable that these relatively low temperatures are limiting in themselves, it is evident that sub-surface soil temperature does have an important effect on the rate of evaporation of moisture from the soil. The study of soil temperatures has also further demonstrated the value of even a slight cover of leaf litter in equalizing soil temperatures and lowering the maximum, thereby preventing excessive evaporation. Further study is needed of the effect of high surface temperatures which may become limiting on certain exposed south slopes.

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(2) Day, R. K., and DenUyl, D. - The Natural Regeneration of Farm Woods Following the Exclusion of Livestock.
Purdue Univ. Agr. Exp. Sta. Bull. No. 368, 1932.

Wind Velocity. In grazed woodlands which have passed into or beyond the "transition" stage of decadence, wind movement and air currents are much more noticeable than in ungraced or lightly grazed areas. This adversely affects a number of interrelated environmental factors, particularly soil moisture and temperature, relative humidity, and air temperature. Even slight air movement removes the blanket of more or less saturated air surrounding the leaves, increasing the diffusion gradient and thus accelerating the rate of transpiration until wilting occurs. Any increase in transpiration rate is injurious when the soil water is at the critical point.

The Cumulative Effect of Increased Transpiration and Evaporation. It has been previously stated that woodlands in which a complete sod cover has been established through a partial opening up of the stand probably suffer a greater loss of soil moisture than any other stage in the transition from dense forest to open pasture. In these woods the factors which tend to conserve moisture have been materially disturbed through the compacting of the soil surface, the disappearance of the protective leaf litter and mull, the elimination of the shrubby undergrowth and tree seedlings which served as an effective barrier against free wind movements, and through the formation of a sod cover. On the other hand, the tremendous amount of transpiration which takes place in the dense forest has been only moderately reduced through the reduction in the number of trees. It seems probable that the considerable increase in evaporation directly from the soil under conditions which approach those of an open prairie is not materially offset by this decrease in transpiration from the overhead stand. This opinion was verified indirectly in a series of trenched and untrenched plots in which an attempt was made to evaluate the influences of crown canopy and sod cover separately. This was found to be impossible, due to the fact that the increase in soil moisture content, which was anticipated through the reduction of tree root competition, was offset by the increased growth and transpiration of blue-grass on the trenched plots.

To summarize this progress report, soil moisture appears to be the principal limiting factor in the satisfactory regeneration and rehabilitation of those grazed woodlands which have reached the advanced stages of decadence. The other factors apparently become limiting chiefly through their interrelated effect on the moisture factor.

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Station Note
No. 23

May 1, 1935.

# The Influence of Degree of Cutting on the Survival and Early Growth of Chestnut Oak Seedlings

by
John G. Kuenzel, Assistant Silviculturist.

Knowledge of silvicultural methods necessary to secure adequate hardwood reproduction of desirable seedling growth is very meager. In the Central Hardwood Region the regeneration of stands deteriorated by fire, grazing, or exhaustive cutting is an important problem. A good restocking of thrifty young seedlings adapted to these sites is highly desirable, especially in stands now consisting largely of decadent or inferior sprouts.

To gain a better understanding of the requirements of native seedlings during early life, a series of studies has been undertaken by the Central States Forest Experiment Station. This progress report deals with growth characteristics of chestnut oak (Quercus montana, Willd) seedlings, and provides an insight to the requirements and behavior of this species during early development.

Germination Study. An exceedingly heavy crop of chestnut oak acorns occurred over the entire range of this species in the Central States during the autumn of 1928. In studying germination and early survival of the resulting seedlings in Chio and Indiana, Barrett (2) found that litter depth, aspect, and, to a certain extent, overhead shade were the most important factors affecting establishment.

The influence of overhead cover in promoting a small but significant additional germination of chestnut oak seedlings is attributed to the beneficial effect of reduced site exposure. As pointed out by Korstian (3) and substantiated by observations of members of the Central States Station (1), this beneficial effect includes the preservation of the forest soil in a condition of optimum density and porosity most favorable to moisture retention and root penetration.

Establishment of Plots. To determine the best methods of developing seedling chestnut oak stands where reproduction was already present, sample plots were established during 1929 on the Clark County State Forest in the "Knobs" region of southern Indiana. Chestnut oak is confined to the non-calcareous hills and ridges of this forest, and occurs in almost pure stands, or mixed with white oak, black oak, post oak, hickories, red maple, Virginia pine, ironwood, dogwood, and chestnut. Sprout "twin trees" are common in these second growth stands.

Three sample plots, each including fifty 10 x 10 link (0.001 acre) quadrats, were established and periodically remeasured for the purpose of this study. Most of the trees were in the 70-80 year age class, with 65 per cent of the basal area in dominant and codominant trees ranging in size

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from 6 to 16 inches D.B.H., and with a stocking of from 600 to 800 trees per acre. The check plot (Plot I), comprising 0.2 acre, was left untreated. Plot II, 0.25 acre in size, was partially cut, leaving about 60 trees, or approximately 50 per cent of the original basal area. Plot III, also 0.25 acre in size, was clear cut. An isolation area given treatment identical with that of the plot was made on a 50 foot strip around each plot.

Seedling Survival. Portions of the remeasurement data are presented in the accompanying tables. Table I shows the effect of cutting the overstory on the survival of seedlings resulting from the 1928 acorn crop of chestnut oak.

Table I

| Plot | Treatment | Total Number of Seedlings at end of Growing Season Per Acre | | | | |
|---|---|---|---|---|---|---|
| | | 1929 | 1930 | 1931 | 1932 | 1934 |
| I | No cutting | 48,500 | 28,380 | 16,660 | 12,400 | 5,200 |
| II | Partial cutting | 36,080 | 24,400 | 14,540 | 14,280 | 12,460 |
| III | Clear cutting | 38,260 | 28,180 | 11,320 | 10,380 | 10,380 |

The most common factors influencing seedling mortality on these plots included drought, rodent injury, root decay, and galls. Severe drought, particularly that of 1930, caused heavy mortality. Mice and rabbits were very destructive to seedlings during the first year or two. Oak galls resulted in dead stems and formation of seedling sprouts. Within the uncut check plot there was apparent a constant decrease in the number of seedlings and a steady diminishing of the vigor of the survivors. The superior survival of seedlings on the partially cut plot is evident, but their small size and lack of development reduces their significance. The number of seedlings remaining after five years on the clear cut plot is still sufficient to insure good stocking, and the fact that mortality was low and growth good in the past three growing seasons is significant.

Seedling Growth. Table II, showing the effect of cutting the overstory on the growth of chestnut oak seedlings, clearly indicates that partial cutting resulted in little or no improvement in seedling growth of chestnut oak over the uncut area, whereas the clear cutting resulted in seedlings 4.7 times as large as those on the uncut plot during the period 1929 to 1934.

Table II

| Plot | Treatment | Average Height of Seedlings at end of Growing Season In Inches | | | | |
|---|---|---|---|---|---|---|
| | | 1929 | 1930 | 1931 | 1932 | 1934 |
| I | No cutting | 3.7 | 4.7 | 5.1 | 5.3 | 6.5 |
| II | Partial cutting | 3.9 | 4.7 | 5.4 | 5.3 | 8.1 |
| III | Clear cutting | 3.3 | 5.6 | 11.2 | 22.8 | 30.8 |

It is even more significant to note that in the uncut plot few seedlings exceeded 8.0 inches in total height by 1934, in the partially cut plot the largest were 14.0 inches tall, whereas in the clear cut plot many seedlings had grown to a height of 53.0 inches.

Sprout Growth. Abundant and rapidly growing sprouts of chestnut oak increase the difficulties of securing seedling regeneration after cutting. Within the clear cut plot there were 276 clumps totaling 2460 sprouts per acre with an average height of 124 inches, or about 4 times as large as the seedlings. Some of the most vigorous sprouts were 16 feet tall in 1934. A comparison of subsequent sprout and seedling growth is being made in this plot, to determine whether or not the seedling growth can compete successfully with the fast starting sprouts. On one portion of the plot the sprouts have been cut back to favor the seedlings.

The difficulties of securing satisfactory advanced reproduction through selection cutting in the chestnut oak type are emphasized both by the failure of seedlings to grow well, as evident in Plot II, and by the behavior of sprout growth in comparison with that on the clear cut area. 268 clumps with 1140 sprouts per acre were found, having an average height of 58 inches. Rapid growth of these was not being maintained by 1934. Many of the openings in the partially cut plot were being occupied by seedlings and sprouts of sassafras, red maple, flowering dogwood, and scarlet oak. These species were much more abundant here than in the clear cut plot. This suggests the difficulties in attempting to maintain good all-aged stands through selection cutting in the oak type on relatively dry sites. Such practice usually favors reproduction of the more tolerant species of minor importance.

Summary. It becomes apparent, from this study, that an overhead stand of chestnut oak is necessary for an abundant crop of seedlings to become established, but they grow very slowly and do not develop beyond the seedling stage. Partial cutting does not permit satisfactory seedling growth and likewise hinders sprout development of oak, but leads to the formation of a slow-growing understory of tolerant minor species. Clear cutting, after oak reproduction is established, encourages rapid growth both of seedlings and sprouts, but the fast growth of the latter may threaten the ultimate development of the seedlings. Obviously more studies are needed to determine the best methods of reproducing oak stands.

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Station Note No. 22

# OBSERVATIONS ON THE NURSERY DEVELOPMENT OF SHORTLEAF PINE SEEDLINGS

January 25, 1935.

A. G. Chapman, Associate Conservationist

During a forest planting survey made by the Central States Forest Experiment Station in 1934, observations indicated that shortleaf pine may become one of the principal species to be used in reforesting extensive areas of eroding, submarginal lands found throughout the southern, unglaciated portion of the Central States. Many of the sites that once produced excellent stands of hardwoods have become so deteriorated by cultivation and erosion that only the less exacting coniferous species are likely to succeed, at least until favorable site conditions are restored to some extent by a cover crop of trees. Most northern and exotic conifers are poorly adapted to the conditions of soil and climate that make tree establishment difficult in certain portions of the Central States. Native species, such as pitch, Virginia, and shortleaf pine and red cedar are far better suited to this environment. Of these, shortleaf pine offers the greatest promise for most planting projects, particularly from the standpoint of profitable timber production, although the other native species may be better adapted to the poorest sites.

Shortleaf pine occurs naturally in this region in southern Ohio, in the eastern third of Kentucky, in scattered localities in Tennessee, throughout much of the Ozark region of northern Arkansas and southeastern Missouri, and in a very limited area in southwestern Illinois . It is usually found on residual sandstone soils on exposed slopes and excessively drained upland flats, or on chert-mantled ridges. Many of the older residents of these areas agree that the local distribution of shortleaf pine has been greatly extended in recent years by natural regeneration of seedlings in abandoned fields. Establishment of this species on poor, dry sites, under conditions unfavorable to most trees, indicates its probable success when planted.

It is generally recognized that the survival and establishment of a forest plantation is largely dependent upon the use of good nursery stock. Therefore, during the recent planting survey, particular attention was given to the methods and results of shortleaf pine seedling production in the various Federal, State, and private nurseries of the region as well as to the behavior of natural regeneration of this species. A brief summary of these observations may be helpful to nurserymen who have had little or no experience in growing shortleaf pine planting stock.

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Since the extensive planting operations of the region must be undertaken on sites quite xerophytic, it is necessary to produce seedlings which will give the highest percentages of survival and establishment. To accomplish this, special consideration must be given to such characteristics of seedlings as shoot-root ratio, degree of succulence, and size of stock. The nursery practices which control these characteristics to the greatest extent are shading, watering, selection of seedbed soil, density of seedlings, length of time left in seedbed, and fertilizing.

Shading. The response of shaded seedlings to the factors of their environment after planting is often less favorable than that of seedlings developed under conditions of the planting site. It is apparent that the almost universal shading of coniferous seedbeds without regard to species, as practiced by a few nurserymen, is a "hangover" from the production of seedlings of species exotic to the region; e. g., spruces, Norway pine, firs, larches, etc. It is common experience in this region that without shade during the first season there is a very high rate of mortality of these exotics. The loss is particularly heavy on sandy soils and may be attributed to excessive heating at the soil surface, and, to a lesser degree, to the long periods of exposure to direct sun rays. Where old plantations or individual trees of these exotics are found in the region, very little or no reproduction occurs under conditions where shortleaf pine reproduces abundantly. This partially explains the limit placed upon the southern extension of some of the northern conifers and other species.

Although shading does conserve soil moisture, no nurseryman seems to be able to justify the shading of shortleaf pine seedlings. On the contrary, nurserymen who have been producing planting stock of this species in open beds for the last four or five years have discontinued the use of shades. Without shade, the shoot-root ratios are lowered, which mean lower ratios between water transpired and water absorbed; also, they find less succulent foliage and stems more resistant to the direct rays of the sun, low winter temperatures, and late spring frosts after dormancy is broken. Plantings on the Central Division of the Ozark National Forest in Arkansas, made from 1-0 stock grown in both open and shaded beds at the Forest Service Nursery at Russellville, show better survival with the unshaded seedlings. The planting experience of the region further substantiates the preference for unshaded seedlings.

Watering. It is imperative that the amount of water applied to seedbeds during the growing season be controlled to obtain desirable planting stock. Watering should correspond closely to the rainfall which the seedlings normally receive under field conditions. This practice, with certain modifications, is being conducted in several nurseries in the Central States. If the soil moisture at the time of seeding is somewhat low, sprinkling is done to insure maximum germination and early growth. Later in the season there may be critical periods of drought when watering is necessary to maintain a suitable growth rate. The danger in too frequent watering arises from producing high shoot-root ratios and increased succulence, characteristics common to shaded seedlings. The behavior here is largely due to increased availability of the essential mineral elements.

Soil Conditions. Within the climatic range of shortleaf pine, soil moisture and temperature seem to be important in limiting its natural distribution to certain areas of sandy or cherty soils. The extremely low moisture content of these well-drained soil materials during the dry seasons is less favorable for the survival of hardwood than pine seedlings. The competition between the broadleaf species and the intolerant shortleaf pine is thereby reduced; and if seed of the pine is available, a stand frequently develops. Also, shortleaf pine seedlings are damaged less than many of the hardwood seedlings by frequent high temperatures at the surface of sandy and rocky soils.

While not all the soil factors which are significantly correlated with good sowing and planting practices are known, it is in well-drained, sandy loam seedbeds that the best nursery results are obtained. Often it is advisable to improve the physical condition of soils high in colloids by rotation of some green manure crop with a crop of seedlings. Sometimes two green manure crops are plowed under in a single season; e. g., an early crop of rye followed by soy beans. Oats, cowpeas, sweet clover and buckwheat are also used.

Age of Seedlings. The age of shortleaf pine seedlings planted in the region depends at present somewhat upon the size, which varies with the increase in length of growing season from north to south. In general, planters in the northern half of the region prefer 1-1 stock, even when orders are placed with southern nurseries where size is expected to be greater than that of locally grown material. In the northern nurseries where seedlings are grown under shades, 5 to 10 inches seem to be the maximum heights attained in one year. In the southern half of the region, where 10 to 12-inch seedlings develop in one season, most planters prefer 1-0 stock. Shortleaf pine planting stock should not be more than two years old for field planting, since the roots of the larger seedlings are damaged in handling. The use of unnecessarily large planting stock is costly and increases the risk of unsatisfactory tree development. It is suggested that quality of stock and not size should be given most consideration. While excellent survival has been realized by planters of 1-1 stock in Kentucky, Ohio, and Illinois, it is thought that good success may be obtained with properly grown 1-0 stock when the ground cover is not too tall and dense, in which case even 1-1 seedlings are often suppressed. The development of an adequate root system during the shorter growing season in the north may be the criterion. Should the planting of the smaller 1-0 seedlings prove satisfactory in the northern sections of the unglaciated area, there is the added advantage of cheaper production.

Rate of Seeding. Rate of seeding in beds varies appreciably, and often may be a limiting factor in the production of high quality stock. Certain factors, such as viability, size, and purity of seed, quality of seedbed soil, method of sowing (broadcast or drilling), and length of time seedlings are to be left in beds, control rate of seeding. Few of these need any discussion. As the quality of seedbed soil decreases the amount of seed per unit area may be slightly increased, because of the

less crowded condition among the smaller plants produced. When broadcast sowing is practiced, the rate of seeding may be increased over that of drilling. Drilling is usually preferred, especially when seed is distributed in ribbon-like bands by drills and not concentrated in bottoms of V-shaped drill rows, because of uniform depth of covering of seed, ease of cultivation, weeding, and lifting. In a few nurseries the plants are left in the seedbeds for two years. When this practice is followed, fewer seed must be sown. Where 1-1 stock is desired, it is usually transplanted in the late autumn of the first season or before breaking of dormancy the second season, autumn transplanting being the more common. Where seed is drilled, eight rows to the 4-foot bed, either by a seeder or by hand, thirty to forty 1-0 seedlings per square foot may be expected as an average crop. In some nurseries as high as sixty seedlings are grown per square foot. Usually from 4 to 8 ounces of seed per 100 square feet of seedbed area are sown.

It is often desirable for the nurseryman to have available some simple method of determining the quantity of seed to sow per unit area of seedbed. Below is a simple formula used by Philip Bryan at the Ozark National Forest Nursery, Russellville, Arkansas, as reported in the Ozark Nursery report for 1933.

Formula: $O = \frac{AD}{GSZ}$

O = ounces of seed to sow

A = area of beds in square feet

D = density desired per square foot

G = germination per cent of seed

S = number of seed per ounce

Z = varying factor, an expression of allowance for damping-off, and for difference in seedbed and laboratory germination tests. (Bryan uses a factor of .3.)

Source of Seed. While there has been only limited investigation of the success of shortleaf pine seedlings grown from locally produced seed and from seed produced under different climatic conditions, experience with this and other species indicates that locally grown seed should be used. Several instances in the northern part of the region have shown stock developed from southern seed to be much more susceptible to frost injury than that from seed collected locally. No information is available regarding the quality of stock grown in the south from northern seed, or of stock produced from seed collected in different latitudes. As a rule, the use of local seed is safest.

Control of Damping-off Fungi. Shortleaf pine seedlings are not so susceptible to damage by damping-off fungi as are many other species, probably because of quick germination and rapid early growth. Good nursery practices are unfavorable to the development of these parasitic organisms. Early plowing and working of the soil, followed by thorough discing and harrowing at intervals, during which the soil is exposed to long periods of full sunlight, destroy many germinating spores and fully developed mycelia. Furthermore, a well-prepared bed is sufficiently aerated to retard damping-off fungi. Omission of frames and shades from

the beds lowers the relative humidity at the soil surface, a condition less favorable for the fungous growth than higher humidities. Limiting the amount of water applied to beds sufficient to insure good germination reduces chances for severe infections. Surface application of compost or leaf litter, made to increase organic matter of the soil and to conserve moisture, is a practice usually favorable to damping-off fungi and should be dispensed with when possible. When difficulty from damping-off is experienced by failure to control the physical conditions of the environment, damage may be minimized by one of these methods: (1) Apply 8 to 12 ounces of sulfuric acid per 100 square feet soon after sowing. The commercial grade is as effective as chemically pure acid. (2) A powdered charcoal-formalin mixture may be dusted over the seedbed before or after sowing at the rate of 65 to 100 ounces to 100 square feet of seedbed. The mixture should contain 6% of a 40% solution of formaldehyde, an inexpensive preparation. (3) Before sowing, approximately 50 gallons of a 3% solution of formaldehyde may be sprinkled over 100 square feet of seedbed, which is then covered with burlap or paper, and left for three or four days before sowing. This may be ineffective unless sterilized tools and sterilized seed are used. (4) Semesan may be used for dusting seed previous to sowing. (5) Cuprocide (cuprous oxide), a commercial seed protectant, may be used for dusting seed before sowing.

Fertilizing. Definite information regarding the use of commercial fertilizers and their effects upon shortleaf pine seedlings is not available. Several projects, designed to furnish needed information, are in progress in the region. Since the species reproduces and grows moderately well on poor, abandoned field soils, the necessity for heavy applications of fertilizer is questionable. This is further indicated by the usual small response of conifers to variations in quantities of essential mineral elements, as compared with that of hardwoods. Fertilizers which are low in nitrogen are most commonly used. Perhaps, the danger of producing undesirable succulent plants with high shoot-root ratios from fertilizing is not as great as among the hardwood species; but since available essential mineral elements are necessary for the growth of all green plants, deficiencies of one or many of them must not be overlooked. Since these vary with individual nursery sites, general rules for fertilizing are of little value. A half and half mixture of bone meal and acid phosphate, 12.5 pounds per 100 square feet of seedbed, or a 5-8-7 commercial mixture, approximately 1.8 pounds per 100 square feet of seedbed, have been recommended.

To correct a chlorotic condition in seedlings, spray the leaves with a manganese sulphate solution, 8 parts manganese sulphate per million parts of water; increase the magnesium in the soil by the addition of small quantities of pulverized dolomitic limestone; or spray a 1% solution of ferrous sulphate on the leaves, sufficient to wet.

The production of well balanced seedlings having sturdy, well lignified stems and well developed, compact root systems, is a problem confronting each nurseryman for his particular site conditions. Desirable stock is the result of not one or two site factors, but of a complex of factors operating in varying intensities and proportions from time to time and from site to site. Even with the production of good nursery stock, unless seedlings are properly handled from the lifting operation to the completion of the planting job, satisfactory results will not be obtained.

INTERMOUNTAIN STATION
Central Reference File
No.

U. S. Department of Agriculture - Forest Service
CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

Station Note
No. 21

December 8, 1934

# A BLACK WALNUT VOLUME TABLE FOR CONTENTS IN BOARD FEET

Plantation Black Walnut
(Juglans nigra Linn.)
Central States Region

L. F. Kellogg — 1932 — Scribner Rule 10.0" top d.i.b.

| Diameter breast high | | Total Height in Feet | | | | | Basis: No. of trees |
|---|---|---|---|---|---|---|---|
| | | 50 | 60 | 70 | 80 | 90 | |
| | | Volume in board feet | | | | | |
| Inches (o.b.) | (i.b.) | | | | | | |
| 13 | 11.2 | 24 | 31 | 37 | 44 | 50 | 20 |
| 14 | 12.0 | 44 | 54 | 65 | 77 | 87 | 16 |
| 15 | 12.9 | 64 | 79 | 95 | 112 | 127 | 16 |
| 16 | 13.8 | 85 | 105 | 125 | 145 | 162 | 13 |
| 17 | 14.7 | 107 | 130 | 153 | 175 | 195 | 10 |
| 18 | 15.6 | | 154 | 178 | 204 | 226 | 6 |
| 19 | 16.4 | | 176 | 204 | 233 | 258 | 4 |
| 20 | 17.3 | | 198 | 230 | 260 | 288 | 2 |
| 21 | 18.2 | | 220 | 253 | 286 | 316 | 1 |
| 22 | 19.1 | | 241 | 276 | 311 | 343 | 1 |
| 23 | 20.0 | | 263 | 300 | 338 | 372 | - |
| Basis: No. of trees | | 3 | 12 | 56 | 17 | 1 | 89 |

Trees measured by the Central States Forest Experiment Station in Kentucky, Indiana, Illinois and Iowa. Stump height 1.0 ft. Top diameter inside bark 10.0". Scaled in 12-ft. log lengths with trimming allowance of 0.3 ft. Additional top sections scaled as fractions of a 12-ft.-10.0" log. Trees with less than 1 log scaled down to a 6-ft. section. Aggregate deviation: Chart is 0.93% high. Average percentage deviation on 61 trees, 13.9" and over in D.B.H., 11.7%. Block indicates extent of basic data. Prepared by the alinement chart method.

This is the fifth and last volume table for plantation black walnut, prepared from the study of walnut throughout the Central States.

INTERMOUNTAIN STATION
Central Reference File
No. 0.723

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CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

Station Note
No. 20

December 8, 1934

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# A BLACK WALNUT VOLUME TABLE FOR CONTENTS IN BOARD FEET

Plantation Black Walnut
(Juglans nigra Linn.)
Central States Region

L. F. Kellogg

1932

Scribner Rule
8.0" top d.i.b.

| Diameter breast high | | Total Height in Feet | | | | | | Basis: No. of trees |
|---|---|---|---|---|---|---|---|---|
| | | 40 | 50 | 60 | 70 | 80 | 90 | |
| | | Volume in board feet | | | | | | |
| Inches (o.b.) | (i.b.) | | | | | | | |
| 10 | 8.5 | | | 17 | 18 | 20 | | 2 |
| 11 | 9.4 | 19 | 21 | 25 | 31 | 40 | 48 | 26 |
| 12 | 10.3 | 25 | 31 | 42 | 52 | 62 | 72 | 29 |
| 13 | 11.1 | 38 | 48 | 60 | 72 | 84 | 96 | 27 |
| 14 | 12.0 | 54 | 65 | 78 | 92 | 105 | 120 | 16 |
| 15 | 12.9 | 68 | 81 | 95 | 110 | 127 | 145 | 16 |
| 16 | 13.8 | 83 | 96 | 112 | 130 | 150 | 170 | 13 |
| 17 | 14.7 | | 112 | 130 | 152 | 175 | 200 | 10 |
| 18 | 15.6 | | 129 | 150 | 174 | 201 | 230 | 6 |
| 19 | 16.4 | | 148 | 172 | 200 | 230 | 262 | 4 |
| 20 | 17.3 | | | 195 | 227 | 261 | 297 | 2 |
| 21 | 18.2 | | | 220 | 255 | 293 | 332 | 1 |
| 22 | 19.1 | | | 245 | 284 | 325 | 368 | 1 |
| 23 | 20.0 | | | | 313 | 359 | 405 | - |
| Basis: No. of Trees | | - | 12 | 39 | 77 | 24 | 1 | 133 |

Trees measured by the Central States Forest Experiment Station in Kentucky, Indiana, Illinois and Iowa. Stump height 1.0 ft. Top diameter inside bark 8.0". Scaled in 12-ft. log lengths with trimming allowance of 0.3 ft. Additional top sections scaled as fractions of a 12-ft.-8.0" log. Trees with less than 1 log scaled down to a 6-ft. section. Aggregate deviation: Chart is 0.04% low. Average percentage deviation on 125 trees, 11.7" and over in D.B.H., 10.3%. Block indicates extent of basic data. Prepared by the alinement chart method.

This is the fourth of five volume tables for plantation black walnut, prepared from the study of walnut throughout the Central States.

U. S. Department of Agriculture - Forest Service
CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

Station Note
No. 19

December 8, 1934

# A BLACK WALNUT VOLUME TABLE FOR CONTENTS IN BOARD FEET

Plantation Black Walnut
(Juglans nigra Linn.)
Central States Region

E. R. Lexen
V. A. Clements

1930

International 1/8" kerf
5.0" top d.i.b.

| Diameter breast high | | Total Height in Feet | | | | | | | Basis: No. of trees |
|---|---|---|---|---|---|---|---|---|---|
| | | 30 | 40 | 50 | 60 | 70 | 80 | 90 | |
| | | Volume in board feet | | | | | | | |
| Inches (o.b.) | (i.b.) | | | | | | | | |
| 7 | 5.9 | 1 | 5 | 9 | 14 | 18 | | | 13 |
| 8 | 6.8 | 4 | 11 | 18 | 24 | 29 | | | 35 |
| 9 | 7.6 | 9 | 18 | 26 | 34 | 42 | 49 | | 25 |
| 10 | 8.5 | 14 | 25 | 36 | 47 | 58 | 67 | | 29 |
| 11 | 9.4 | | 32 | 46 | 60 | 75 | 87 | 96 | 29 |
| 12 | 10.2 | | 39 | 56 | 75 | 92 | 106 | 119 | 29 |
| 13 | 11.2 | | 48 | 69 | 90 | 110 | 128 | 144 | 27 |
| 14 | 12.0 | | 56 | 81 | 106 | 130 | 151 | 170 | 16 |
| 15 | 12.9 | | 65 | 94 | 123 | 150 | 177 | 197 | 16 |
| 16 | 13.8 | | | 107 | 140 | 175 | 200 | 227 | 13 |
| 17 | 14.6 | | | 123 | 160 | 200 | 230 | 260 | 10 |
| 18 | 15.5 | | | 140 | 184 | 227 | 262 | 296 | 6 |
| 19 | 16.4 | | | 158 | 208 | 256 | 297 | 335 | 4 |
| 20 | 17.3 | | | | 230 | 286 | 332 | 376 | 2 |
| 21 | 18.2 | | | | 257 | 318 | 368 | 415 | 1 |
| 22 | 19.0 | | | | 282 | 350 | 405 | 458 | 1 |
| 23 | 19.9 | | | | 312 | 383 | 450 | 500 | - |
| Basis: No. of trees | | - | 12 | 41 | 92 | 86 | 24 | 1 | 256 |

Based on trees measured by the Central States Forest Experiment Station in Kentucky, Indiana, Illinois and Iowa, under the supervision of L. F. Kellogg. Stump height 1.0 ft. Top diameter inside bark 5.0". Scaled in 12-ft log lengths with trimming allowance of 0.3 ft. Additional top sections scaled as fractions of a 12-ft-5.0' log. Aggregate deviation. Chart is 0.6% low. Average percentage deviation on 215 trees, 7.0' and over, 8.49%. Block indicates extent of basic data. Prepared by the alinement chart method in the Washington Office.

This is the third of five volume tables for plantation black walnut, prepared from the study of walnut throughout the Central States.

U. S. Department of Agriculture - Forest Service
CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

Station Note
No. 18

December 8, 1934

# A BLACK WALNUT VOLUME TABLE FOR CONTENTS IN MERCHANTABLE CUBIC FEET

Plantation Black Walnut
(Juglans nigra Linn.)
Central States Region

B. R. Lexen — 1930

Merchantable stem with bark
Cubic Feet
4.0" top d.o.b.

| Diameter breast high | Total Height in Feet: 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Basis: No. of Trees |
|---|---|---|---|---|---|---|---|---|---|
| | Volume in Cubic Feet | | | | | | | | |
| Inches | | | | | | | | | |
| 5 | 0.87 | 1.29 | 1.68 | 2.08 | 2.43 | 2.81 | | | 36 |
| 6 | 1.61 | 2.38 | 3.12 | 3.85 | 4.55 | 5.25 | | | 31 |
| 7 | 2.36 | 3.45 | 4.58 | 5.60 | 6.65 | 7.70 | | | 35 |
| 8 | | 4.70 | 6.10 | 7.55 | 8.95 | 10.4 | 11.9 | | 35 |
| 9 | | 5.95 | 7.85 | 9.70 | 11.6 | 13.4 | 15.2 | | 25 |
| 10 | | 7.30 | 9.55 | 11.9 | 14.1 | 16.5 | 18.9 | | 29 |
| 11 | | | 11.6 | 14.4 | 17.5 | 20.2 | 23.0 | 25.8 | 29 |
| 12 | | | 13.8 | 17.2 | 20.7 | 24.0 | 27.2 | 30.5 | 29 |
| 13 | | | 16.1 | 20.2 | 24.2 | 28.0 | 31.9 | 35.8 | 27 |
| 14 | | | 18.8 | 23.4 | 27.9 | 32.5 | 37.0 | 41.0 | 16 |
| 15 | | | 21.6 | 26.8 | 32.0 | 37.2 | 42.0 | 47.5 | 16 |
| 16 | | | | 30.2 | 36.1 | 42.0 | 48.0 | 54.0 | 13 |
| 17 | | | | 34.0 | 40.0 | 47.0 | 54.0 | 61.0 | 10 |
| 18 | | | | 38.0 | 45.3 | 53.5 | 61.0 | 69.0 | 6 |
| 19 | | | | 42.0 | 51.0 | 59.5 | 68.0 | 77.0 | 4 |
| 20 | | | | 46.5 | 56.0 | 66.0 | 75.5 | 85.5 | 2 |
| 21 | | | | 52.0 | 62.5 | 73.0 | 84.0 | 95.0 | 1 |
| 22 | | | | 57.0 | 68.5 | 80.0 | 93.0 | 105 | 1 |
| Basis: No. of Trees | 2 | 27 | 45 | 64 | 96 | 86 | 24 | 1 | 345 |

Based on trees measured by Central States Forest Experiment Station in Kentucky, Indiana, Illinois and Iowa, under the supervision of L. F. Kellogg. Stump height 1.0 ft. Top diameter 4.0" d.o.b. Minimum merchantable length 4.0 ft. Volume measured by planimeter. Aggregate deviation: Chart 0.27% high. Average percentage deviation on 326 trees, 5.0" and over D.B.H., 5.4%. Block indicates extent of basic data. Prepared by the alinement chart method in the Washington Office.

This is the second of five volume tables for plantation black walnut prepared from the study of walnut throughout the Central States.

U. S. Department of Agriculture - Forest Service
CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

Station Note
No. 17

December 8, 1934

# A BLACK WALNUT VOLUME TABLE FOR CONTENTS IN CUBIC FEET

Plantation Black Walnut
(Juglans nigra Linn.)
Central States Region

B. R. Lexen

1930

Entire stem less bark
Cubic Feet

| Diameter breast high | | Total Height in Feet | | | | | | | | | Basis: No. of Trees |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | |
| | | Volume in cubic feet | | | | | | | | | |
| Inches (o.b.) | (i.b.) | | | | | | | | | | |
| 1 | 0.8 | .03 | .05 | .07 | | | | | | | 14 |
| 2 | 1.6 | .10 | .18 | .26 | .34 | .42 | | | | | 13 |
| 3 | 2.4 | .21 | .38 | .54 | .70 | .86 | 1.02 | | | | 20 |
| 4 | 3.3 | .36 | .65 | .91 | 1.19 | 1.47 | 1.77 | 2.0 | | | 20 |
| 5 | 4.1 | .55 | .98 | 1.39 | 1.83 | 2.28 | 2.70 | 3.1 | 3.5 | | 24 |
| 6 | 5.0 | .79 | 1.40 | 2.00 | 2.62 | 3.30 | 3.96 | 4.6 | 5.1 | | 31 |
| 7 | 5.9 | 1.06 | 1.89 | 2.70 | 3.58 | 4.50 | 5.4 | 6.2 | 6.9 | | 35 |
| 8 | 6.7 | | 2.42 | 3.50 | 4.65 | 5.80 | 7.0 | 8.0 | 9.0 | 9.7 | 35 |
| 9 | 7.6 | | 3.05 | 4.45 | 5.90 | 7.40 | 8.8 | 10.1 | 11.3 | 12.3 | 25 |
| 10 | 8.5 | | 3.75 | 5.50 | 7.30 | 9.1 | 10.9 | 12.6 | 14.0 | 15.5 | 29 |
| 11 | 9.4 | | | 6.55 | 8.75 | 11.0 | 13.3 | 15.4 | 17.2 | 18.8 | 29 |
| 12 | 10.3 | | | 7.8 | 10.3 | 13.0 | 15.9 | 18.3 | 20.2 | 22.0 | 29 |
| 13 | 11.2 | | | 9.1 | 12.1 | 15.4 | 18.7 | 21.3 | 24.0 | 26.0 | 27 |
| 14 | 12.0 | | | 10.4 | 13.9 | 17.8 | 21.1 | 24.5 | 27.3 | 29.6 | 16 |
| 15 | 12.9 | | | 11.9 | 16.0 | 20.0 | 24.2 | 28.0 | 31 | 34 | 16 |
| 16 | 13.8 | | | 13.7 | 18.3 | 22.8 | 27.5 | 31.5 | 35 | 38 | 13 |
| 17 | 14.7 | | | | | 25.8 | 30.8 | 35.5 | 40 | 43 | 10 |
| 18 | 15.6 | | | | | 28.6 | 34.0 | 39.5 | 44 | 48 | 6 |
| 19 | 16.5 | | | | | 31.8 | 38.2 | 44.2 | 50 | 55 | 4 |
| 20 | 17.3 | | | | | | 42 | 50 | 55 | 60 | 2 |
| 21 | 18.2 | | | | | | 46 | 54 | 60 | 65 | 1 |
| 22 | 19.1 | | | | | | 51 | 60 | 66 | 72 | 1 |
| 23 | 19.9 | | | | | | 55 | 65 | 72 | 79 | |
| Basis: No. of Trees | | 4 | 26 | 50 | 49 | 64 | 96 | 86 | 24 | 1 | 400 |

Based on trees measured by Central States Forest Experiment Station in Kentucky, Indiana, Illinois and Iowa, under the supervision of L. F. Kellogg. Stump height 1.0 ft. Volume measured by planimeter. Aggregate deviation: chart 0.49% low. Average percentage deviation 5.1%. Block indicates extent of basic data. Prepared by the alinement chart method in the Washington Office.

This is the first of five volume tables for plantation black walnut, prepared from the study of walnut throughout the Central States.

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Columbus, Ohio

Station Note
No. 16

November 20, 1934.

# THE EFFECT OF FOREST BURNING AND PASTURING IN THE OZARKS ON THE WATER ABSORPTION OF FOREST SOILS

John T. Auten, Silviculturist

The importance of forests in building and retaining soil porosity and water-absorbing capacity can scarcely be overestimated. In many regions, failure of springs and streams, lowering of ground water levels, and serious increase in soil erosion are caused by removing forests from non-agricultural land, or by destroying the effectiveness of forest cover through repeated burning or excessive grazing. Both droughts and floods of recent years have emphasized the necessity of reducing surface water run-off and of improving those conditions of soil and vegetative cover which help to absorb and conserve rainfall.

In a previous report (1) of this Station, soil porosity and rates of water absorption in old-growth woods, second-growth woods, and forest plantations were compared respectively with those of adjacent field soils. It was shown clearly that soil under old-growth forest is much more porous and has a far greater water-holding capacity than the same soil cleared and cultivated or seeded to grass. This was also found to be true of second-growth woods where grazing of livestock had not been permitted. In the case of forest plantations on compacted old-field soil, soil porosity had increased and water absorption capacity had been restored to a great extent during the twenty-five to thirty years during which the plantations had been established.

This former study was conducted chiefly on the glaciated silt-loam and clay soils of the Corn Belt. The few tests of coarser textured sandy soils indicated the retention of more porosity after clearing and cultivation than was found in the finer silts and clays, but the need for more data on sandy soils was apparent. The question also arose as to the porosity of the stony or cherty soils typical of large portions of the extensive Ozark forest region. Of special importance was the determination of the effects of repeated forest burning and excessive grazing, so prevalent in the Ozarks, on the water absorptive capacity of the cherty soils of Missouri and Arkansas, and of the loessal soils of southern Illinois.

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(1) Porosity and Water Absorption of Forest Soils, by John T. Auten. Jour. of Agri. Research, Vol. 46, No. 11, pp. 997-1014. June, 1933. A mimeographed summary of this report has been issued as Station Note No. 8.

To supply these data, during the summer of 1934 a series of tests was made on both cherty and sandy soils of the Sylamore Experimental Forest in northern Arkansas and on yellow silt loam soils of the Shawnee Experimental Forest in southern Illinois. Both areas are in the unglaciated region of the Ozark highland which extends from southern Illinois through southern Missouri and northern Arkansas. The Sylamore area is representative of the great Ozark forest region of Missouri and Arkansas, while the Shawnee area is typical of the unglaciated loess-mantled areas of southern Illinois, southern Indiana, and southeastern Ohio.

It proved impracticable to use the brass tubes of the former study for absorption tests in cherty soil; consequently water absorption was determined by pouring four successive one-liter portions of water into a square 12-inch wooden frame sealed with wet clay to the mineral soil from which the leaf litter had been removed. The inside of the open frame was lined with strips of galvanized sheet iron the width of the frame. The joining edges of the metal were soldered to prevent leakage. This method of procedure proved highly successful and gave striking results of the relative water-absorbing capacities under the conditions of the experiment. One hundred tests were made on each site and the differences in rates of absorption were very significant. The actual absorption rates found by the frame method naturally vary considerably from those secured in the previous work with 2-inch brass tubes, but the relative results under the soil conditions tested are convincingly similar. With very heavy rainfall, where the surface water on bare soil becomes turbid and the soil puddled, the ratio of absorption in undisturbed woods to absorption in burned woods or pasture would no doubt be much higher, especially on steep slopes.

The comparative volume weights of a 6-inch soil column $2\frac{1}{2}$ inches in diameter were 523, 654, and 667 grams, respectively, for undisturbed forest, burned forest, and pasture soils of the southern Illinois yellow silt loam. Stated in percentages, the upper six inches of the pasture soil was about 28 per cent heavier, and the burned forest soil was 25 per cent heavier, than the same volume of soil from the undisturbed forest. These differences represent increases in compactness and corresponding losses in porosity when the forest is cleared and pastured or when the woods are repeatedly and severely burned. It was obviously impossible to secure comparable weights of the Arkansas cherty silt loam, because of its stony structure.

The following table gives the number of cubic centimeters of water absorbed per second, for each of the four successive liters applied, under the various conditions of soil tested in this experiment.

RATE OF WATER ABSORPTION IN CUBIC CENTIMETERS PER SECOND PER SQUARE FOOT OF SOIL (a)

| SOIL TYPE | SITE CONDITIONS | FIRST LITER | SECOND LITER | THIRD LITER | FOURTH LITER |
|---|---|---|---|---|---|
| Yellow silt loam Illinois | Undisturbed oak woods | 21.83 | 23.36 | 22.78 | 21.23 |
| | Burned oak woods | 7.60 | 4.63 | 3.40 | 2.64 |
| | Open pasture | 2.52 | 1.34 | 1.01 | .86 |
| Cherty silt loam Arkansas | Undisturbed oak woods | 55.87(c) | 44.87(c) | 38.76 | 32.05 |
| | Burned oak woods | 14.25 | 9.78 | 6.12(b) | 5.10(b) |
| | Open pasture | 17.73(c) | 10.47(c) | 6.16 | 4.74 |
| | Old-field pine woods | 53.19 | 35.21 | 21.10(b) | 14.71(b) |
| | Open pasture | 12.32 | 7.66 | 8.04(b) | 6.37(b) |
| Sandy soil Arkansas | Undisturbed oak woods | 64.10 | 46.08 | 40.00 | 30.50 |
| | Open pasture | 24.33 | 16.84 | 14.35 | 12.92 |

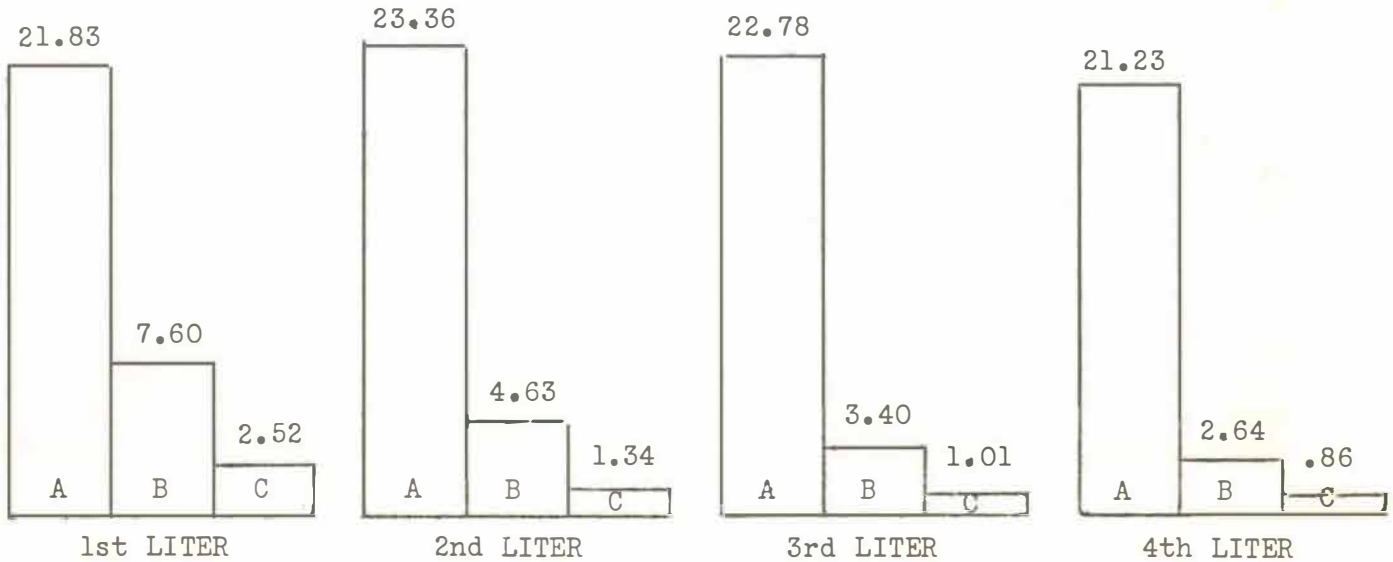
(a) Each figure represents the average of 100 tests unless otherwise indicated. All items over three times Standard Deviation are eliminated.
(b) Less than 100 tests. (c) 200 tests.

The block diagrams below, based upon the figures of the table, show very clearly that in the case of the Illinois silt loam soils there is a very great decrease in the water absorptive capacities of severely burned forest and pastured soils compared with the undisturbed woods. In the case of the latter, the rate of absorption, for each successive liter of water applied, remained relatively constant throughout the test, whereas in the case of the burned woods and pastured soils, the rate of absorption diminished with each application of water. For both the burned woods and pastured soils the rate of absorption of the fourth liter was only 35 per cent that of the first.

AVERAGE VOLUMES OF WATER IN CUBIC CENTIMETERS PER SECOND PER SQUARE FOOT ABSORBED WHEN APPLIED IN FOUR SUCCESSIVE ONE-LITER PORTIONS

A = Undisturbed Woods B = Burned Woods C = Open Pasture

Yellow Silt Loam - Southern Illinois



This decrease in water absorption can be explained by the compaction of bare surface soil which occurs during rainfall, and by the sealing of the soil pores as the finer particles are washed downward. The porosity of the forest soil, which is preserved by the protective covering of leaf litter, is lost when the litter is destroyed by fire or by the grazing of livestock. Trampling further compacts the pasture soils.

Furthermore, an exposed, dry, structureless soil is very difficult to wet; dry soil particles act very much as if they were oiled, and capillarity does not become active until water makes actual contact with the soil particles. This contact is made much more slowly with dry soil than with the slightly moist soil found under leaf litter. This slowness to absorb water is a very important factor following a drought. On steep slopes the run-off of rainfall may be considerable before the dry, compacted soils are able to function even with their reduced water absorptive capacities.

The cherty Ozark soil was found to absorb water more rapidly than did the Illinois silt loam, as might be expected from its stony structure, yet the soils of the repeatedly burned woods and the pastures lost their porosity to a remarkable degree. The diagrams on page 5 show that the rate of absorption of the undisturbed forest soils decreased somewhat with each successive application of water, but not nearly as rapidly as it did in the soils of the burned woods and the pastures. When the fourth liter of water was applied, the rate of absorption in the undisturbed woods was 68 per cent of the first application, whereas, in the case of the burned woods and pasture, it had dropped to 36 per cent and 27 per cent, respectively.

By consulting the table, it may be seen that although the undisturbed woods on sand and on cherty silt loam have similar rates of absorption, the rate for the pasture on sand is greater than that for pasture on the cherty silt loam. The rate for the fourth application of water on the sand pasture is 2.72 times as great as that on cherty silt loam pasture. This indicates that sandy soil loses less porosity relatively than does a silt loam. It must not be overlooked, however, that the absorption rate for woods on sand decreased about 2/3 when the land was cleared and pastured. It is evident that even on sand there is a significant loss of water absorption brought about by exposure and pasturing.

The tests on the old-field pine site show that porosity is regained when a cleared area is reforested with pine. In this particular case, the results were less striking, no doubt, because of the fact that the pine area had been repeatedly burned up until about six years ago. The pine stand was about 48 years old.

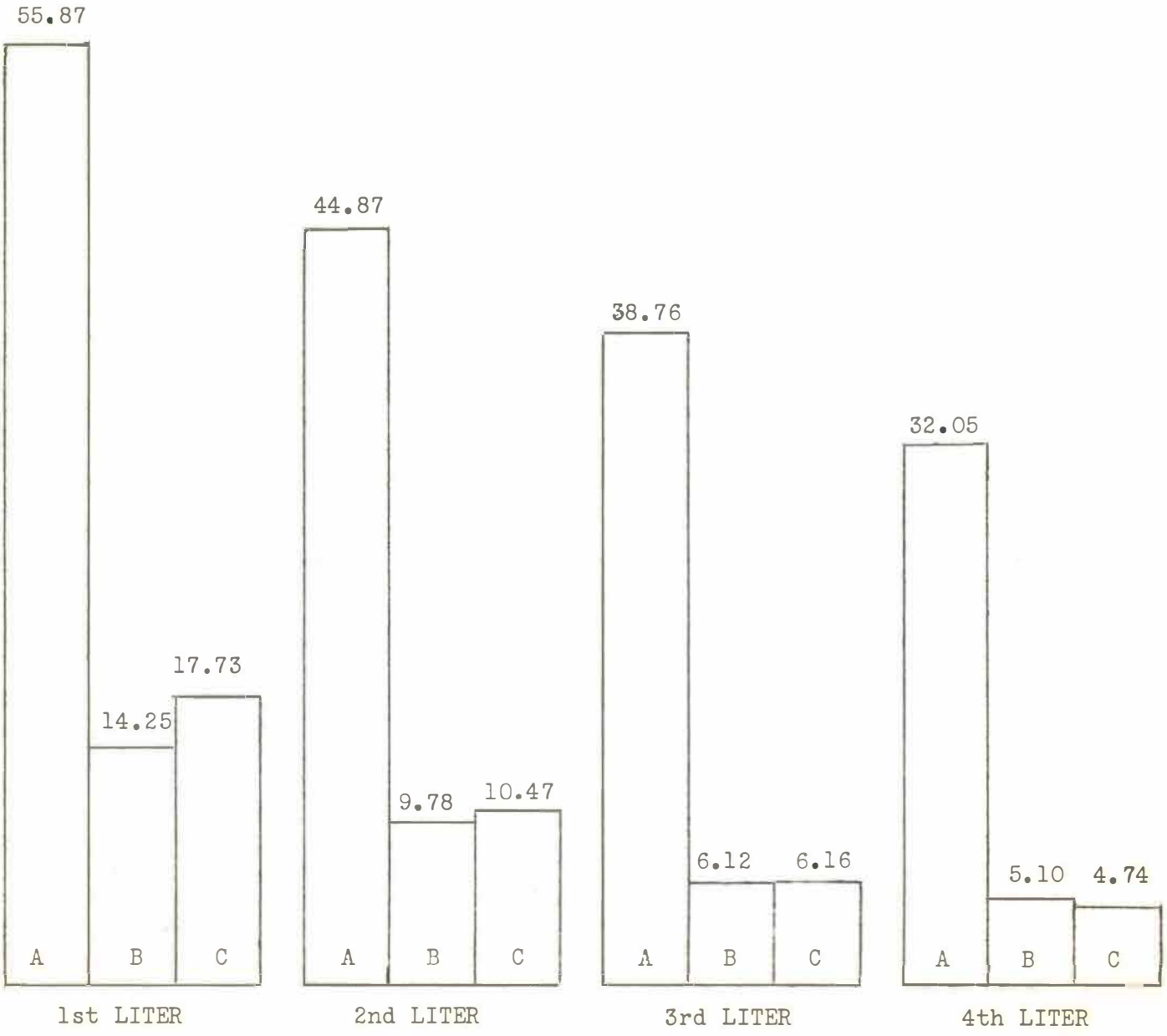
The results of this series of water absorption tests, together with those of the original study which it supplements, offer convincing data on the effectiveness with which forest cover influences water absorption and retards run-off. On silt loam and clay soils of fine texture this influence is very great, and even on stony and sandy soils it is most significant. Under conditions of heavy rainfall on steep slopes, the actual run-off

is undoubtedly much greater on unprotected soils than the data of this experiment indicate. The results also emphasize the need for forest protection against fires and excessive pasturing of livestock, and for reforestation of cleared, non-agricultural lands, as important measures of run-off control. The cost of engineering works for erosion control, flood control, and water conservation may be reduced greatly, and their efficiency increased, by forest conservation and restoration.

AVERAGE VOLUMES OF WATER IN CUBIC CENTIMETERS PER SECOND PER SQUARE FOOT ABSORBED WHEN APPLIED IN FOUR SUCCESSIVE ONE-LITER PORTIONS

A = Undisturbed Woods B = Burned Woods C = Open Pasture

Cherty Silt Loam - Northern Arkansas



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Columbus, Ohio

Station Note
No. 15

Oct. 15, 1934.

# FAILURE OF BLACK LOCUST - CONIFEROUS MIXTURES IN THE CENTRAL STATES

L. F. Kellogg,
Associate Silviculturist.

Forest planting is certain to occupy a leading place in the rehabilitation of waste lands in the Central States. The magnitude of the task of reforestation is indicated by the millions of acres of land involved, including marginal and submarginal areas, abandoned farms, denuded forest lands, washed and gullied fields and pastures, and idle acres too severely deteriorated to justify expenditures to restore them to productive use for crops or pasture. Many critical areas demand an immediate forest cover for erosion control and watershed protection.

Black locust is being used very extensively in present planting operations, especially those for erosion control. The extensive root system which develops with the establishment of the tree is capable of holding and stabilizing the soil surface, sprouts vigorously and prolifically, and contributes to increased soil fertility through the formation of root nodules with fixation of nitrogen.

It is generally recognized that mixed plantations of two or more species are better in many ways than pure stands of one species. Planted black locust has been found to be most thrifty (all factors considered) when growing in mixture with other species. The locust appears healthier; a better litter is formed which is more protective to the soil; and last but not least, the investigation of the locust borer by R. C. Hall has shown that the amount of attack and damage may be considerably reduced, even to the point of minor importance, by growing locust in mixed stands. Such mixtures more nearly approach natural stands in composition, with material safeguards against pathological and entomological attacks, which are the heritage of pure stands.

In considering the large planting problem in the Central States, many foresters including those of this Station, have advanced the suggestion of mixing conifers with black locust. Present planting operations frequently are following this suggestion. Some state forestry departments are recommending it to private cooperators and planters. The purpose behind the suggestion is entirely creditable. The object is to establish a thoroughly protective and productive tree cover; to bind the soil quickly (with the locust root system); to produce a more adequate leaf litter than that formed by locust alone; to reduce as far as possible the amount of damage by the locust borer; and to secure productive crops of timber, in addition to those of locust, or in case the locust succumbs to borer attack.

Before large amounts of time, labor, trees, and money are spent in following this plan, it is desirable to establish its likelihood of success. Several indicators are now at hand, thanks to the earlier plantings and experiments of several organizations. The Central States Forest Experiment Station has just finished a survey of plantations in the unglaciated portion of this region, during which all known plantings, young as well as old, were visited to appraise their condition, growth, and likelihood of success. In this survey, conducted by A. G. Chapman, the field party found a number of plantings of black locust-coniferous mixtures established under a variety of conditions. Consistent failure of the conifers was found to occur.

Without exception these mixtures have indicated real difficulties in securing favorable growth of conifers in mixture with black locust. The development of conifers in these plantings has been so poor and mortality has been so general that these mixtures, as made, are considered unsuccessful. It is the intent of this discussion to sound a warning against a continuation of past methods of planting locust-coniferous mixtures in one operation, and to urge experimentation in other methods of establishing mixtures, not overlooking the use and encouragement of volunteer hardwoods.

The species that have been observed, planted simultaneously with locust, or plantations in which root sprouts of locust have volunteered, include the following:

| | | |
|---|---|---|
| White pine | Ponderosa pine | Norway spruce |
| Jack pine | Scotch pine | Japanese larch |
| Red pine | Austrian pine | European larch |
| | Shortleaf pine | |

These plantings were found in Ohio, Indiana, Illinois, and Kentucky. None were found in Missouri or Arkansas. Some of the older plantings are on strip coal lands, some on tight, poorly-drained soils of Illinoian glaciation, and some on residual clay banks. One is on loess. (Tennessee is now starting mixtures of locust with loblolly and shortleaf pines, but the plantations are still too recent to yield indications of success or failure.)

In no instances were conifers found to be vigorous beneath the locust. Before death occurs, it was observed that pine tips droop and turn brown. On strip coal lands, jack and Scotch pine were found dead beneath locust in one case; growth of red and Scotch pine was at a standstill in other mixtures with locust, although the pines alone were growing quite vigorously on adjacent spoil banks or fields. On another area sycamore and locust were overtopping red pines which were beginning to die. Death of Norway spruce planted beneath locust has been observed. The spruce-locust planting in Saginaw Forest at Ann Arbor, Michigan, is an exception and is the best appearing mixture with conifers found to date.

In a plantation established on loessial soil in 1928, red pine, white pine, Japanese larch, and European larch were mixed with the locust. All conifers failed. In 1929 the locust was underplanted again with conifers, substituting Austrian for white pine. In 1931 replanting was made with Scotch and Austrian pine. In 1934 a few pitch pine seedlings were used. All the conifers have been a failure, and the locust trees, although young, have closed their crowns and have produced stems of almost post size.

In one planting locust had made splendid growth while Scotch pine beneath was still of seedling size. Adjacent to this stand, ponderosa and Scotch pine, planted simultaneously, had reached heights of 15 feet. Yet the volunteer locust root sprouts were producing an advancing thicket which already was overtopping the adjacent pines. Height growth of the sprouts was 3 to 7 feet in one year's time.

Some of the causes of the coniferous failures are evident. The use of exotic, northern, and western species poorly adapted to the climatic conditions of this region is doubtless one cause.

Lack of light apparently is another. It is to be expected that the locust will establish more quickly and easily than the pine. The success of such mixtures hinges on the ability of the conifer, once it becomes established, to push up beneath or through the locust crown cover. This was not found to take place. Apparently light of a suitable intensity and quality for conifers to survive and grow does not filter through a closed locust canopy. Therefore, planting the two species simultaneously in one operation may be expected to fail.

Lack of moisture has been suggested as a cause. The recent years of drouth apparently were not a critical factor, since pines generally can survive a lower wilting point than hardwoods. In one case the soil was found to be visibly moist around drooping and browning red pines beneath locust, and quite dry around adjacent erect, thrifty young pines out in the open.

Excessive nitrogen from decomposition of nodules on locust roots is not a factor contributing to the failure of conifers. Nitrogen from this source becomes available continuously, and dissipates rather readily. It does not accumulate in great quantities, nor is it concentrated as in animal or bird residues. On the other hand, the death of large, thrifty white pines growing adjacent to locusts has been observed, indicating that there may be a locust toxin or some other factor inimical to conifers.

The success of releasing the suppressed pines by cutting the locust seems improbable, because of the vigorous sprouting capacity of locust. Furthermore such a step would be most unwise because vigorous root development of locust acts more effectively and quickly in tying down eroding soil than does that of any pine in the same period of time. Although no such instances were found, it is possible that a heavy infestation of locust borer might hold the locust trees in check sufficiently to allow the pine to dominate the stand. Volunteer eastern red cedar has been found in locust plantings, when these were rather open, on poor sites (for locust) and heavily infested with the locust borer.

The evidence of this plantation survey indicates that certain conifers cannot be planted simultaneously with black locust with the expectation of securing thrifty growth or even survival of the conifer. It is probable that where very heavy attacks of the borer retard the locust, the conifers may dominate the stand. It follows that underplanting older locust trees with conifers holds little promise of success in this region.

Obviously much additional experimentation is needed. It may be that native yellow pines will succeed where exotics have failed, -- particularly if the pines are given a good start before introducing the locust or if the locusts are widely spaced. R. C. Hall has found pitch pine and locust growing well together in the Pennsylvania foothills along the Juniata river. The pitch pine was 5 to 8 years older, however, and had the advantage of several years in height growth. It has been suggested that, for erosion control planting where an immediate cover is needed for critical areas, a plan of mixed planting in groups might meet with success. Under this suggestion the locust could be planted in and adjacent to the gullies, with pine on the areas between gullies. There is a possibility that the native yellow pines might be used successfully in mixtures of this type. Such a planting has not been found and it is highly advisable to test the idea experimentally before giving it general use or recommendation.

Foresters should not overlook the value of hardwoods in mixture with locust on favorable sites. An excellent locust planting with a volunteer understory of hard maple indicates that tolerant hardwoods may be good species to use in mixture. Yield plots in locust have recorded a considerable number of natural volunteer hardwoods which will grow beneath or in association with locust. Such natural succession indicates mixtures which foresters will be wise to follow and simulate. The acceptance and encouragement of most volunteer hardwood growth in planted locust groves cannot be urged too strongly.

U. S. Department of Agriculture - Forest Service
CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

# Table of STANDARD BOLT CUTS
## Showing the Number and Diameter by Size Classes

Plantation BLACK LOCUST
(Robinia pseudoacacia, Linn)
Central States Region

Station Note
No. 14

August 2, 1934.

L. F. Kellogg

1934

Standard Bolts = 4.15 Ft.
Stump Height = 0.5 Ft.

| D.B.H. of Tree | Total Ht. | Diam. of Bolts i.b. at small end - inches | | | | | | Total No. of Bolts | Volume of Bolts | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 6 | 7 | 8 | 9 | 10 | | International Rule 1/8" kerf | Scribner Rule |
| | | No. of 4.15-ft. Bolts | | | | | | | | |
| Inches | Ft. | | | | | | | No. | Bd. Ft. | Bd. Ft. |
| 7 | 30 | 1 | | | | | | 1 | 2 | 2 |
| | 40 | 2 | | | | | | 2 | 5 | 4 |
| | 50 | 2 | | | | | | 2 | 5 | 4 |
| | 60 | 3 | | | | | | 3 | 8 | 6 |
| | 70 | 4 | | | | | | 4 | 10 | 8 |
| 8 | 30 | 1 | 1 | | | | | 2 | 8 | 6 |
| | 40 | 2 | 1 | | | | | 3 | 10 | 8 |
| | 50 | 2 | 2 | | | | | 4 | 15 | 12 |
| | 60 | 3 | 2 | | | | | 5 | 18 | 14 |
| | 70 | 3 | 3 | | | | | 6 | 22 | 18 |
| 9 | 40 | 2 | 1 | 1 | | | | 4 | 18 | 14 |
| | 50 | 2 | 1 | 2 | | | | 5 | 25 | 20 |
| | 60 | 2 | 2 | 2 | | | | 6 | 30 | 24 |
| | 70 | 3 | 3 | 2 | | | | 8 | 38 | 30 |
| | 80 | 3 | 4 | 2 | | | | 9 | 42 | 34 |
| 10 | 40 | 1 | 1 | 1 | 1 | | | 4 | 25 | 20 |
| | 50 | 2 | 1 | 2 | 1 | | | 6 | 35 | 28 |
| | 60 | 2 | 2 | 2 | 1 | | | 7 | 40 | 32 |
| | 70 | 2 | 3 | 3 | 1 | | | 9 | 52 | 42 |
| | 80 | 3 | 3 | 3 | 2 | | | 11 | 65 | 52 |
| 11 | 40 | | 1 | 1 | 1 | 1 | | 4 | 35 | 28 |
| | 50 | 1 | 1 | 2 | 1 | 1 | | 6 | 45 | 36 |
| | 60 | 1 | 2 | 2 | 2 | 1 | | 8 | 60 | 48 |
| | 70 | 2 | 2 | 3 | 2 | 1 | | 10 | 70 | 56 |
| | 80 | 2 | 2 | 3 | 3 | 1 | | 11 | 80 | 64 |
| | 90 | 2 | 3 | 3 | 4 | 1 | | 13 | 95 | 76 |

(over)

| D.B.H. of Tree | Total Ht. | Diam. of Bolts i.b. at small end - inches | | | | | | | | | | | | Total No. of Bolts | Volume of Bolts | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | | Intern'l Rule 1/8" kerf | Scribner Rule |
| | | No. of 4.15-ft. Bolts | | | | | | | | | | | | | | |
| Inches | Ft. | | | | | | | | | | | | | No. | Bd. Ft. | Bd. Ft. |
| 12 | 40 | 1 | 1 | 1 | | 1 | 1 | | | | | | | 5 | 42 | 36 |
| | 50 | 1 | 2 | 1 | 1 | 1 | 1 | | | | | | | 7 | 58 | 48 |
| | 60 | 2 | 1 | 2 | 2 | 1 | 1 | | | | | | | 9 | 72 | 60 |
| | 70 | 1 | 2 | 2 | 2 | 2 | 1 | | | | | | | 10 | 88 | 72 |
| | 80 | 1 | 3 | 2 | 2 | 3 | 1 | | | | | | | 12 | 105 | 86 |
| | 90 | 2 | 2 | 3 | 3 | 3 | 1 | | | | | | | 14 | 120 | 98 |
| 13 | 60 | 1 | 2 | 1 | 1 | 2 | 2 | | | | | | | 9 | 85 | 71 |
| | 70 | 1 | 2 | 2 | 2 | 2 | 2 | | | | | | | 11 | 102 | 85 |
| | 80 | 2 | 2 | 2 | 2 | 2 | 3 | | | | | | | 13 | 120 | 100 |
| | 90 | 1 | 2 | 2 | 3 | 3 | 3 | | | | | | | 14 | 140 | 116 |
| 14 | 60 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | | | | | | 9 | 102 | 84 |
| | 70 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | | | | | | 11 | 128 | 106 |
| | 80 | 1 | 2 | 1 | 2 | 2 | 3 | 2 | | | | | | 13 | 150 | 126 |
| | 90 | 1 | 2 | 2 | 2 | 3 | 2 | 3 | | | | | | 15 | 175 | 144 |
| 15 | 60 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | | | | | 10 | 125 | 102 |
| | 70 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 2 | | | | | 12 | 155 | 126 |
| | 80 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | | | | | 14 | 182 | 149 |
| 16 | 60 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | | | | 10 | 148 | 120 |
| | 70 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | | | | 12 | 178 | 144 |
| | 80 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | | | | 14 | 212 | 174 |
| 17 | 60 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 10 | 162 | 132 |
| | 70 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | | | 12 | 208 | 170 |
| | 80 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | | | 14 | 245 | 199 |
| 18 | 60 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 10 | 198 | 164 |
| | 70 | | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | | 12 | 242 | 200 |
| | 80 | | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | | 14 | 282 | 233 |
| 19 | 70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 13 | 275 | 226 |
| | 80 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 15 | 325 | 268 |

Black locust is cut in bolt form for manufacture into insulator pins of several types, wagon hubs, wheel spokes, and treenails for wooden ships. As a rule locust bolts are cut at least 4 feet 2 inches and not over 8 feet 4 inches long, but very good bolts 3 feet or 10 feet long will often be accepted by manufacturers.

Bolts from large trees are preferred. Dealers figure 400 board feet to the cord for black locust bolts.

Manufacturers just about "break even" on bolts of 5"-7" diameter, and begin to make a profit when they are 8" and over in diameter. For wagon hubs, bolts of 9" and over are required.

Those who desire to know more about the stumpage, costs, and utilization of black locust in bolt form are referred to:

Cuno, J. B.

1930 - Utilization of black locust.
U. S. Dept. of Agri. Circular No. 131.
20 pp. illus. specifications. appendix.
Govt. Print. Off. Wash. D. C.

The foregoing table was constructed from average taper curves prepared by the F. S. Baker method of subordinate form quotients, and based on 396 stem measurements taken in Indiana, Illinois, and Ohio. The averages were made on heights at percentile diameters rather than on diameters at given heights. From the final taper curves, standard bolts 4.15 feet in length above a 0.5 foot stump were scaled. Fractional inches of small diameters were rounded off to the next lower inch class for conservatism. Curves of number of bolts over D.B.H. by height classes, and then over height by D.B.H. classes were prepared to check inconsistencies. Bolts have been rounded off to the nearest whole bolt rather than to carry fractional values which cannot be utilized.

No opportunity has come to check this table against actual bolt-cutting operations. Anyone having such an opportunity can give material service by comparing tabular values with those secured by careful utilization in trees of the same D.B.H.-height classes. This Station will appreciate such checks and criticism of this table.

This is the sixth of several tables for plantation black locust.

Files

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CENTRAL STATES FOREST EXPERIMENT STATION

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Publications
Station Notes #13

August 22, 1934.

Dear Sir:

Enclosed herewith are volume tables of plantation black locust prepared by L. F. Kellogg in the form of Station Notes. Number 13 gives the contents of black locust trees in numbers of 7-foot fence posts of various sizes, and Number 14 gives the contents in numbers of 4-foot bolts, in which form black locust is commonly utilized. The total merchantable board foot volume of the bolts is also given. Users of these tables should note that the total contents of a tree are given either in 4-inch, 5-inch, or 6-inch posts, whereas the bolt table gives the total number of bolts of all sizes. For example, Table No. 13 shows that a black locust 10 inches in diameter and 40 feet tall will yield 6 4-inch posts, or 4 5-inch posts, or 2 6-inch posts; table No. 14 gives the contents as 1 8-inch bolt, 1 7-inch, 1 6-inch, and 1 5-inch, or a total of 4 bolts.

Other volume tables of plantation black locust have been prepared, as mimeographed Station Notes in order to make them immediately available, as follows:

No. 7 Total volume in cubic feet.
No. 9 Merchantable volume in board feet - International Rule.
No. 10 Merchantable volume in board feet - Scribner Rule.
No. 11 Merchantable volume in cubic feet.

These and other Station Notes issued from time to time as current progress reports of studies and investigations of the Central States Forest Experiment Station are available for distribution upon request.

Sincerely yours,

Willis M Baker.

WMB/CH
Enc.

Willis M. Baker,
Director.

U. S. Department of Agriculture - Forest Service
CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

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Preliminary Table
of
POST CONTENTS
Plantation BLACK LOCUST
(Robinia pseudoacacia, Linn)
Central States Region

Station Note
No. 13

July 15, 1934

L. F. Kellogg

1934 Post Length: 7 Feet 1/
Minimum Diam.of post:4in.2/ D.I.B.

| D.B.H. of Tree | Total Height | Contents of tree in ROUND or Equivalent SPLIT Posts 3/ | | | D.B.H. of Tree | Total Height | Contents of tree in ROUND or Equivalent SPLIT Posts 3/ | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 4" d.i.b. | 5" d.i.b. | 6" d.i.b. | | | 4" d.i.b. | 5" d.i.b. | 6" d.i.b. |
| Inches | Feet | No. | No. | No. | Inches | Feet | No. | No. | No. |
| 6 | 30 | 1 | -- | -- | 12 | 40 | 9 | 6 | 3 |
| | 40 | 1 | -- | -- | | 50 | 12 | 7 | 4 |
| | 50 | 2 | -- | -- | | 60 | 16 | 9 | 5 |
| | 60 | 2 | -- | -- | | 70 | 20 | 11 | 6 |
| 7 | 30 | 2 | 1 | -- | | 80 | 24 | 14 | 7 |
| | 40 | 2 | 1 | -- | | 90 | 28 | 16 | 9 |
| | 50 | 3 | 1 | -- | 13 | 60 | 20 | 12 | 7 |
| | 60 | 3 | 2 | -- | | 70 | 24 | 14 | 8 |
| | 70 | 4 | 2 | -- | | 80 | 28 | 17 | 9 |
| 8 | 30 | 3 | 1 | -- | | 90 | 32 | 20 | 11 |
| | 40 | 4 | 2 | 1 | 14 | 60 | 23 | 14 | 8 |
| | 50 | 4 | 2 | 1 | | 70 | 28 | 17 | 10 |
| | 60 | 5 | 3 | 1 | | 80 | 33 | 20 | 12 |
| | 70 | 6 | 4 | 1 | | 90 | 38 | 24 | 13 |
| 9 | 40 | 5 | 3 | 1 | 15 | 60 | 26 | 16 | 10 |
| | 50 | 6 | 3 | 2 | | 70 | 32 | 20 | 12 |
| | 60 | 8 | 4 | 2 | | 80 | 39 | 25 | 14 |
| | 70 | 10 | 5 | 3 | 16 | 60 | 30 | 19 | 11 |
| | 80 | 11 | 6 | 3 | | 70 | 37 | 23 | 14 |
| 10 | 40 | 6 | 4 | 2 | | 80 | 45 | 28 | 17 |
| | 50 | 8 | 5 | 2 | 17 | 60 | 33 | 22 | 13 |
| | 60 | 11 | 6 | 3 | | 70 | 42 | 26 | 17 |
| | 70 | 13 | 7 | 4 | | 80 | 52 | 32 | 20 |
| | 80 | 16 | 9 | 5 | | | | | |
| 11 | 40 | 7 | 5 | 2 | 18 | 60 | 38 | 25 | 15 |
| | 50 | 10 | 6 | 3 | | 70 | 48 | 30 | 19 |
| | 60 | 13 | 7 | 4 | | 80 | 58 | 36 | 23 |
| | 70 | 17 | 9 | 5 | 19 | 70 | 54 | 33 | 22 |
| | 80 | 20 | 11 | 6 | | 80 | 66 | 40 | 26 |
| | 90 | 23 | 13 | 7 | 20 | 70 | 60 | 37 | 25 |
| | | | | | | 80 | 73 | 44 | 29 |

1/ Posts of $7\frac{1}{2}$, 8 and 10 feet are sometimes cut.

2/ The 4-inch class includes posts 4.0 to 4.9 inches in diameter measured at the small end, including sap; the 5-inch class all posts 5.0 - 5.9 inches; etc. Smaller posts are frequently cut for home use. As in the case of most volume tables, no allowance has been made for cull.

3/ Conversion factors used in reducing large sized cuts to their equivalent in 4, 5, or 6-inch posts:

| Split Post Size | Diameter at Small end of Round post cuts | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| | Equivalent Split Posts - Number | | | | | | | | | | | | | | | |
| Inches | | | | | | | | | | | | | | | | |
| 4 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 |
| 5 | - | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 8 | 9 | 10 | 11 | 13 | 14 |
| 6 | - | - | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

Prepared by division of diameters (expressed as basal area) by the b.a. of 4, 5, and 6 inches respectively. Additional fractions of posts eliminated, for conservatism.

The table was constructed from taper curves based on 396 stem measurements taken in Indiana, Illinois and Ohio, and prepared by the F. S. Baker method of subordinate form quotients. The averages were made on heights at percentile diameters rather than on diameters at given heights. From the final taper curves, post-cuts 7 feet in length above a 0.5 foot stump were scaled and the diameters at the small end of each were taken. Fractional inches were rounded off to the next lower inch class for conservatism. The contents of each post-cut in 4, 5, or 6 inch posts as calculated using the values in footnote 3 above. For each size, curves of number of posts over D.B.H. by height classes, and then over height by D.B.H. classes were prepared to smooth off irregularities. No cognizance was taken of posts from forks or limbs.

No opportunity has come to check this table against actual post cutting operations. Anyone having such an opportunity can give material service by comparing tabular values with those secured by careful utilization in trees of the same D.B.H.-height classes. This Station will appreciate such checks and criticism of this table.

This is the fifth of several volume tables for plantation black locust. As other tables are completed, they will be issued immediately in this form in order to avoid delay in making them available for use.

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Central States Forest Experiment Station
Columbus, Ohio

Station Note
No. 12

June [illegible] 1934

# REDUCE WOODLAND GRAZING BY INCREASING PASTURES

By Ralph K. Day, Assistant Silviculturist

Within the last few months several measures of land use have been initiated which offer distinct opportunities to relieve extensive areas of farm woods in the Central States from further degradation through grazing of livestock. The importance of the farm woods to this region and the serious damage caused by pasturing make it necessary for forestry agencies and woodland owners to take full advantage of these opportunities.

The crop reduction program of the Agricultural Adjustment Administration will apparently result in more lands used for forage and pasture. Various erosion control projects now carried on by several public agencies require forest or grass cover for steep slopes and erosible soils. The acquisition of marginal areas by the Surplus Relief Corporation may lead in many instances to similar management of these lands. The demonstration projects of the Soil Erosion Service in Ohio, Illinois, and elsewhere, are promoting improved agricultural practices which include contour farming, erosion control, and a considerable increase in forage and grass on the steeper slopes. Many progressive farmers may be expected to adopt these improved practices, with the result that extensive areas which cannot be farmed conservatively in corn or similar crops will be put into grass. All of these measures should tend to relieve the present shortage of pastures in the Corn Belt, and should gradually eliminate the necessity for pasturing livestock in the farm woods, which practice has been a major factor in reducing them to their present state of deterioration. The general adoption of the measures of the Lumber Code to sustain and improve forest production should also tend to discourage woodland grazing in the Central States.

This combination of circumstances is called to the attention of forestry, conservation, and agricultural agencies as well as to owners of farm woods, because there appear to be opportunities for checking much of the serious deterioration that has been taking place, and for constructive work in the productive management of a valuable forest asset.

The importance of the farm woods in any well-balanced agricultural or land-use program is becoming widely appreciated. The economic, biotic, aesthetic, and sociologic values gained by retaining certain portions of the land in timber are being recognized as essential to the welfare of any community. Unfortunately, in the face of this increasing importance of farm woods, and the many opportunities they present for profitable forest management, the percentage of woodlands on farms has been decreasing steadily. In many of the better agricultural areas farm woods are approaching extinction.

(Over)

Moreover, most of the woodlands remaining in the Corn Belt are so badly understocked, overmature and decadent that they are becoming of little value for timber production or for any other use as forested lands. Tree regeneration is prevented by the browsing and trampling of livestock, young growth is destroyed, the moisture-conserving and fertility-building leaf litter disappears, the soil becomes compacted, and tree growth declines. A woods pasture is a poor pasture and a poor woods.

Cooperative studies by the Central States Forest Experiment Station and the Purdue Agricultural Experiment Station have shown conclusively that the wide-spread practice of pasturing has been chiefly responsible for the decline in productivity and area of the farm woods. Most farmers fully appreciate that a woods pasture is greatly inferior to a good open pasture, but because of the fact that practically every tillable acre in some sections has been used for corn or forage crops, the woodlands have constituted the only pasture available, and naturally have been thoroughly utilized even at the cost of forest devastation. Over-grazing has not only seriously curtailed the production of timber products, but also has decreased or destroyed the value of many farm woodlands for erosion control, for conservation of soil moisture and underground water, for food and shelter of game and insectivorous bird life, and for wind breaks or shelter belts. If we could calculate accurately the monetary value of the services and benefits which accrue to humans from forested lands, and which have been so extravagantly wasted in this region, we would find that the Corn Belt farmers have paid, and will continue to pay, a tremendous price for their woods forage.

The saving of the farm woods from ultimate destruction and restoring them to productivity has been one of the principal objectives of all public forestry organizations in the Central States; but the total results from all this effort have not been encouraging. In spite of much educational and extension work, many demonstrations of proper woodland management, and even special tax legislation in some states, the practice of grazing the farm woods has been very generally continued. In some instances the farmers have been ignorant of or indifferent to the situation; in others it has been a matter of economic necessity. These same factors have contributed directly to other land abuses, for which various remedies described in the beginning of this paper, are being tried. Every forestry and conservation agency should welcome and assist the movement leading toward better farming methods, increased areas in grass, and economic land use, for it provides an opportunity for saving and restoring the farm woods.

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CENTRAL STATES FOREST EXPERIMENT STATION
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Station Note
No. 11

April 17, 1934

# A BLACK LOCUST VOLUME TABLE FOR CONTENTS IN MERCHANTABLE CUBIC FEET

Plantation BLACK LOCUST
(Robinia pseudoacacia, Linn)
Central Hardwood Region

Merchantable Stem
with bark - Cubic feet
4" Top D.O.B.

L. F. Kellogg 1934

| Diameter Breast High (o.b.) Inches | Total Height in Feet: 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Basis No. of Trees |
|---|---|---|---|---|---|---|---|---|---|
| | Volume in Cubic Feet | | | | | | | | |
| 4 | 0.26 | 0.36 | 0.44 | 0.52 | | | | | 34 |
| 5 | 0.56 | 1.08 | 1.58 | 2.00 | 2.40 | | | | 44 |
| 6 | 0.90 | 1.95 | 2.94 | 3.58 | 4.30 | | | | 29 |
| 7 | 1.34 | 2.90 | 4.20 | 5.30 | 6.30 | 7.20 | | | 30 |
| 8 | | 4.00 | 5.80 | 7.30 | 8.60 | 10.00 | 11.20 | | 21 |
| 9 | | 5.10 | 7.50 | 9.40 | 11.00 | 12.70 | 14.40 | | 39 |
| 10 | | 6.30 | 9.30 | 11.50 | 13.70 | 15.80 | 17.80 | 20.00 | 26 |
| 11 | | | 11.30 | 14.20 | 16.70 | 19.30 | 21.70 | 24.30 | 24 |
| 12 | | | 13.50 | 17.00 | 20.00 | 23.10 | 26.00 | 29.40 | 9 |
| 13 | | | | 19.70 | 23.20 | 26.80 | 30.10 | 34.00 | 11 |
| 14 | | | | 23.00 | 27.00 | 31.00 | 35.00 | 39.50 | 5 |
| 15 | | | | | 31.10 | 35.90 | 40.60 | 46.00 | 2 |
| 16 | | | | | 35.20 | 40.80 | 46.10 | 53.00 | 5 |
| 17 | | | | | 39.50 | 46.00 | 53.00 | 62.00 | 5 |
| 18 | | | | | 45.00 | 53.00 | 62.00 | 72.00 | 3 |
| 19 | | | | | 51.00 | 61.00 | 70.00 | 82.00 | 3 |
| 20 | | | | | 58.00 | 68.00 | 80.00 | 93.00 | -- |
| Basis: No. of Trees | 15 | 37 | 69 | 60 | 36 | 41 | 30 | 2 | 290 |

Trees measured by Central States Forest Experiment Station in Indiana, Illinois, and Ohio. Stump height 1.0 ft. Top diameter 4.0" d.o.b. Volume measured by planimeter. Aggregate deviation: Chart 0.66% low. Average percentage deviation on 283 trees, 9.5%. Block indicates extent of basic data. Prepared by the alinement chart method.

This is the fourth of several volume tables for plantation black locust. As other tables are completed, they will be issued immediately in this form in order to avoid delay in making them available for use.

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CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

Station Note
No. 10

April 12, 1934

# A BLACK LOCUST VOLUME TABLE FOR CONTENTS IN BOARD FEET

Plantation BLACK LOCUST
(Robinia pseudoacacia, Linn)
Central Hardwood Region

L. F. Kellogg — 1934 — Scribner Rule 8" Top D.I.B.

| Diameter Breast High (o.b.) | (i.b.) | Total Height in Feet: 40 | 50 | 60 | 70 | 80 | 90 | Basis: No. of Trees |
|---|---|---|---|---|---|---|---|---|
| | | Volume in Board Feet | | | | | | |
| Inches | | | | | | | | |
| 10 | 8.4 | 10 | 10 | 10 | 10 | 10 | 10 | 5 |
| 11 | 9.3 | 18 | 19 | 21 | 25 | 32 | 42 | 22 |
| 12 | 10.2 | 35 | 38 | 42 | 48 | 57 | 71 | 18 |
| 13 | 11.0 | 52 | 55 | 59 | 66 | 79 | 97 | 8 |
| 14 | 11.9 | | 73 | 79 | 88 | 103 | 126 | 6 |
| 15 | 12.8 | | | 97 | 107 | 126 | 155 | 5 |
| 16 | 13.6 | | | 117 | 130 | 153 | 189 | 4 |
| 17 | 14.5 | | | 139 | 155 | 181 | 225 | 5 |
| 18 | 15.4 | | | 160 | 176 | 209 | 260 | 4 |
| 19 | 16.2 | | | 179 | 200 | 237 | 285 | 4 |
| 20 | 17.1 | | | 200 | 223 | 262 | 325 | --- |
| Basis: No. of trees | | 1 | 9 | 9 | 29 | 21 | 12 | 81 |

Trees measured by the Central States Forest Experiment Station in Indiana, Illinois and Ohio. Stump height 1.0 ft. Top diameter inside bark 8.0". Scaled as 12-ft. log lengths with trimming allowance of 0.3 ft. Additional top sections scaled as fractions of a 12-ft-8.0" log. Aggregate deviation: Chart is 0.36% low. Average percentage deviation on 74 trees, 12.0%. Block indicates extent of basic data. Prepared by the alinement chart method.

This is the third of several volume tables for plantation black locust. As other tables are completed, they will be issued immediately in this form in order to avoid delay in making them available for use.

U. S. Department of Agriculture - Forest Service
CENTRAL STATES FOREST EXPERIMENT STATION
Columbus, Ohio

Station Note
No. 9

March 29, 1934

# A BLACK LOCUST VOLUME TABLE FOR CONTENTS IN BOARD FEET

Plantation BLACK LOCUST
(Robinia pseudoacacia, Linn)
Central Hardwood Region

L. F. Kellogg — 1934 — International 1/8" 5.0" Top D.I.B.

| Diameter Breast High (o.b.) | (i.b.) | Total Height in Feet: 30 | 40 | 50 | 60 | 70 | 80 | 90 | Basis: No. of Trees |
|---|---|---|---|---|---|---|---|---|---|
| Inches | | Volume in Board Feet | | | | | | | |
| 6 | 5.0 | 3 | 3 | 4 | 4 | 5 | | | 29 |
| 7 | 5.9 | 3 | 4 | 7 | 9 | 12 | | | 27 |
| 8 | 6.7 | 3 | 8 | 16 | 21 | 24 | | | 25 |
| 9 | 7.6 | 4 | 18 | 30 | 35 | 40 | 48 | | 27 |
| 10 | 8.4 | | 26 | 40 | 47 | 53 | 64 | 78 | 33 |
| 11 | 9.3 | | 34 | 50 | 59 | 68 | 83 | 102 | 23 |
| 12 | 10.2 | | 43 | 62 | 74 | 85 | 104 | 133 | 18 |
| 13 | 11.0 | | | 74 | 88 | 101 | 128 | 164 | 8 |
| 14 | 11.9 | | | 87 | 104 | 124 | 157 | 200 | 6 |
| 15 | 12.8 | | | 100 | 125 | 147 | 187 | 237 | 5 |
| 16 | 13.6 | | | | 146 | 174 | 218 | 274 | 4 |
| 17 | 14.5 | | | | 171 | 202 | 250 | 316 | 5 |
| 18 | 15.3 | | | | 195 | 230 | 285 | 360 | 4 |
| 19 | 16.2 | | | | 220 | 258 | 321 | 409 | 4 |
| 20 | 17.1 | | | | 246 | 289 | 361 | 463 | - |
| Basis: No. of trees | | 5 | 16 | 75 | 31 | 50 | 29 | 12 | 218 |

Trees measured by the Central States Forest Experiment Station in Indiana, Illinois and Ohio. Stump height 1.0 ft. Top diameter inside bark 5.0". Scaled as 12-ft. log lengths with trimming allowance of 0.3 ft. Additional top sections scaled as fractions of a 12-ft-5.0" log. Aggregate deviation: Chart is 0.22% high. Average percentage deviation on 190 trees, 17.4% Block indicates extent of basic data. Prepared by the alinement chart method.

This is the second of several volume tables for plantation black locust. As other tables are completed, they will be issued immediately in this form in order to avoid delay in making them available for use.

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Columbus, Ohio

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Version 2

Station Note
No. 8

January 15, 1934.

# POROSITY AND WATER ABSORPTION OF FOREST SOILS (1)

By John T. Auten, Silviculturist

The protective influence that forests exert on soil conservation and erosion control is generally recognized, but the relationships between forest litter and soil density, porosity, and water absorptive capacity have been less clearly understood. The changes in soil structure and site productivity that take place after transition from forest to field conditions, and the influence of these changes on tree regeneration and growth, have been little appreciated by those engaged in reforesting waste lands.

To arrive at a better understanding of the relation of soil to the problems of forestry and to determine the influence of forest cover and forest litter, a series of studies has been undertaken, out of which the study of soil porosity and capacity for water absorption was chosen for immediate investigation because of its important bearing on the problems of erosion, flood control, and water conservation, as well as its relation to the successful establishment and maintenance of forest plantations. To determine the contrasting conditions of forest and field soils, a comparison of these characteristics was made in four distinct phases, as follows: (1) old-growth forest soil with open-field soil; (2) second-growth forest soil with open-field soil; (3) grazed with ungrazed second-growth forest soil; (4) forest-plantation soil with open-field soil.

Porosity of Forest and Open Field Soil. From among the very few timber stands in the Central States undisturbed by cutting, grazing, or recent fire, 22 old-growth forest areas were carefully selected in Ohio, Indiana, Michigan, and Illinois. Adjacent field sites were chosen as near the forest as possible, at the same elevation, with soils originally of the same type. Some of the fields had been recently cultivated, others were in sod. Every effort was made to secure paired areas where the change of soil conditions from forest to field could be compared fairly.

Twenty soil tests for apparent specific gravity, or air-dry weight divided by a constant volume, were taken on each area, 10 in the forest and 10 in the adjacent field. Soil samples were taken to a nine-inch depth. All surface litter and duff were removed from the forest site in order that the comparisons might be made purely on the basis of mineral soil. The field soil did not, of course, have the surface organic horizon. Averages of real

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(1) This STATION NOTE summarizes an 18-page illustrated article which appeared in the Journal of Agricultural Research, U.S.D.A., June 1, 1933, (Vol. 46, No. 11, pages 997-1014). Because of the limited distribution of this article, a mimeographed summary has been prepared to meet further requests for information.

specific gravities for forest and field soils indicated only very slight differences: 2.613 ± 0.0032 (standard deviation, 0.020) for forest soils and 2.623 ± 0.007 (standard deviation, 0.044) for field soils. The similarity of these figures eliminates the possibility of the difference in forest and field soil density being caused by difference in the actual weight of the soil material.

When the specific gravities of the different soils were tabulated and averaged, it was found that, in the upper 9 inches the average field soil was 15.3 per cent heavier than the average forest soil. In other words, the upper 9-inch layer of the average field soil was 15 per cent more dense and therefore relatively less porous than the average old-growth forest soil. The difference may be as much as 30 per cent in certain areas. Similar tests conducted in 36 second-growth forest areas in Ohio gave practically the same results. Apparently soil porosity is not lost by cutting provided that forest cover, forest litter, and natural forest conditions are maintained.

The question naturally arises, to what depth does the greater porosity of forest soils extend? Does the difference occur only at the immediate surface or is it distributed throughout the entire 9-inch profile? This point is significant in the survival of tree seedlings, because if the porosity extends to any considerable depth, seedling roots will be able to penetrate much easier and the percentage of survival will be greater. The important question as to difference in water-holding capacities of forested and cultivated areas would be clarified by knowledge of the extent of looseness below the surface.

To settle this question, specific-gravity tests were made in each of three successive 3-inch soil layers in old-growth woods and adjacent field sites. The upper 3 inches of the average field soil was found to be 43.13 per cent heavier than the similar soil layer of the average old-growth forest site adjacent. This difference is based entirely on the mineral soil below the litter and duff accumulation. Similarly, the average density of the 3 to 6-inch soil layer was 12.29 per cent greater in the case of field soils. In the 6 to 9-inch layer the difference in density was negligible.

From these comparisons it may be seen that the greatest difference in density between old-growth woods soil and field soil is in the upper 6 inches. But although the lower layer shows no difference by apparent specific gravity measurements, water-absorption experiments show that the lower layer absorbs water much more rapidly in woods than in field soil.

Water Absorption of Forest Soils. As a corollary to the measurements of apparent specific gravity, a series of water absorption tests were made in old-growth forest areas and adjacent fields. Brass tubes, 2 inches in diameter and 12 inches long, were forced into the soil to a constant depth of 3 cm. This depth proved sufficient to insure that the water would not flow up around the end. The rate of water absorption from these tubes was measured at the depths of 1, 3, and 8 inches. At the first depth, the litter or duff layer was removed. At the second or 3-inch depth, a trench 2 inches deep was dug before the tubes were inserted. At the lower depth, a trench 7 inches deep was dug. This procedure placed the bottoms of the brass tubes approximately 1, 3, and 8 inches below the soil surface.

The relative rates of water absorption in forest and field soils strengthen the conclusion drawn from the density measurements, that forest soils are more porous than field soils. At the 1-inch depth the forest soils absorbed water 50 times as readily as did the field soils; at the 3-inch depth the absorption by forest soils was nearly 15 times as rapid; even at the 8-inch depth, where no difference in soil density was apparent, absorption by forest soils was more than twice that of the field soils. Although these figures are only relative, they clearly indicate the tremendous water-holding capacity of a forested area in contrast to the resistance to absorption and therefore the rapid run-off from cleared lands.

Soil Porosity of Grazed and Ungrazed Woods. Nine second-growth forest sites were selected as typical of grazed and ungrazed woodlands. The grazed areas were in the last stages of forest degradation with only a few old trees, no reproduction, and a ground cover of weeds, grass, and sod. The upper 9-inch layer of the average grazed woodland soil was found to be 15 per cent heavier than the corresponding soil section in an adjacent similar ungrazed area. Excessive pasturing not only prevents tree reproduction but also makes forest exhaustion inevitable through compaction of the soil. The grazed soil is harder, holds less moisture, has poorer aeration, and its general tilth is much deteriorated.

Soil Porosity in Forest Plantations. The final phase of the soil porosity study deals with forest plantation sites. Does soil porosity return to old fields after planting? Thirteen forest plantations from 12 to 60 years of age were measured for soil porosity and compared with adjacent field sites. The difference in weight of the upper 9-inch layers showed that the field soil averaged 13.6 per cent heavier than similar layers of adjacent plantation soil. This difference may be considered to represent a gain in porosity since planting. Field observations show that as soon as a litter is established under a planted stand of trees the soil becomes more porous. The observation was also made that the soil of coniferous plantations gained more in porosity in a given time than did that of hardwoods.

Tests in forest plantation and adjacent field soils also demonstrated that plantation soils have a much greater water absorption capacity. The average rate for the plantation sites at the 1-inch depth was 107 cc per minute compared with 8 cc for the field site. At the 8-inch depth, the averages were 13 and 3 cc per minute for the plantation and field sites respectively. These differences in absorption capacity are in line with the density differences recorded and represent a gain in soil porosity for the plantation since planting.

Functions of Forest Litter. The influence of forest on soil is inseparably connected with forest litter, and the proper production and retention of adequate quantities and kinds of forest litter is dependent upon good silvicultural practice. In the Central States region the accumulation of litter is seldom more than 1 inch in depth. The leaf fall decomposes rapidly and adds its fertility to the soil. The forest litter is, however, of great importance in this region even though it does not accumulate to a great depth. It serves as an absorbent, acts as a mulch or insulation against rapid evaporation, prevents compaction of surface soil by impact of rain, decomposes and furnishes plant food, and serves as a medium for microbiological activities.

Structure of forest soil has been developed through long periods of time. Root penetration, expansion and contraction with changes in temperature and moisture content, and activities of worms, insects, and animals, tend to make soil porous. The forest is a builder and a preserver of soil porosity. The penetration of roots and their eventual decay leave the soil interpenetrated with tubelike cavities. The process of cropping, on the other hand, ultimately decreases soil porosity and favors erosion. The porosity preserved in forest soils by the covering of litter is largely lost in field soils by impact of rain and by the silting and illuviating action of percolating waters.

When the Central States region was settled originally, both good and poor lands were cleared and cultivated. The accumulation of organic matter in the form of incorporated and unincorporated forest litter afforded a temporary supply of plant food, and even the poorer, shallow soils produced well for a time. Then this food supply became exhausted and the land ceased to yield a reasonable return for its cultivation. As the organic matter was oxidized, plant food leached away, and the top soil eroded, the land became increasingly unproductive. The impoverishment under agricultural use of originally fertile forest soil became a major factor in the growth of land abandonment.

Forest Management. Virgin old-growth forests, except as a valuable means of interpreting optimum site conditions, are of no concern in the Central States region. The virgin woods are gone; only second-growth and abandoned fields remain. In the case of second-growth woodlands, careful cutting and consequent opening up of the stand does not destroy soil porosity, provided the forest cover is quickly reestablished, and the litter is not destroyed by fire or grazing. To a great extent soil porosity is an indication of site productivity.

The millions of acres of submarginal and abandoned lands suffering from soil erosion represent a problem of great concern in the Central States. Most of this area was once forested with hardwoods; now that its fertility is largely exhausted an extensive reforestation program is an essential measure of land use planning. The rule in the past on such lands has been to plant the species which formerly grew there naturally or to trust to nature to reseed the area, without realization that the abandoned and deteriorated field soil is usually incapable of permitting the reestablishment of the original tree species. Great difficulty has been experienced in getting hardwood plantations established on such lands; coniferous species, especially the yellow pines, are as a rule more successful. Hardwoods, with the possible exception of black locust, are not so able to survive the adverse conditions that occur in worn-out soil. Mixed planting of locust and native yellow pines is recommended.

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Columbus, Ohio

Station Note
No. 8

Jan. 15, 1934.

# POROSITY AND WATER ABSORPTION OF FOREST SOILS(1)

By John T. Auten, Silviculturist.

Reserve

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Columbus, Ohio

Station Note
No. 8

January 15, 1934.

# POROSITY AND WATER ABSORPTION OF FOREST SOILS(1)

By John T. Auten, Silviculturist

The protective influence that forests exert on soil conservation and erosion control is generally recognized, but the relationships between forest litter and soil density, porosity, and water absorptive capacity have been less clearly understood. The changes in soil structure and site productivity that take place after transition from forest to field conditions, and the influence of these changes on tree regeneration and growth, have been little appreciated by those engaged in reforesting waste lands.

To arrive at a better understanding of the relation of soil to the problems of forestry and to determine the influence of forest cover and forest litter, a series of studies has been undertaken, out of which the study of soil porosity and capacity for water absorption was chosen for immediate investigation because of its important bearing on the problems of erosion, flood control, and water conservation, as well as its relation to the successful establishment and maintenance of forest plantations. To determine the contrasting conditions of forest and field soils, a comparison of these characteristics was made in four distinct phases, as follows: (1) old-growth forest soil with open-field soil; (2) second-growth forest soil with open-field soil; (3) grazed with ungrazed second-growth forest soil; (4) forest-plantation soil with open-field soil.

Porosity of Forest and Open Field Soil. From among the very few timber stands in the Central States undisturbed by cutting, grazing, or recent fire, 22 old-growth forest areas were carefully selected in Ohio, Indiana, Michigan, and Illinois. Adjacent field sites were chosen as near the forest as possible, at the same elevation, with soils originally of the same type. Some of the fields had been recently cultivated, others were in sod. Every effort was made to secure paired areas where the change of soil conditions from forest to field could be compared fairly.

Twenty soil tests for apparent specific gravity, or air-dry weight divided by a constant volume, were taken on each area, 10 in the forest and 10 in the adjacent field. Soil samples were taken to a nine-inch depth. All surface litter and duff were removed from the forest site in order that the comparisons might be made purely on the basis of mineral soil. The field soil did not, of course, have the surface organic horizon. Averages of real

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(1) This STATION NOTE summarizes an 18-page illustrated article which appeared in the Journal of Agricultural Research, U.S.D.A., June 1, 1933, (Vol. 46, No. 11, pages 997-1014). Because of the limited distribution of this article, a mimeographed summary has been prepared to meet further requests for information.

specific gravities for forest and field soils indicated only very slight differences: 2.613 ± 0.0032 (standard deviation, 0.020) for forest soils and 2.623 ± 0.007 (standard deviation, 0.044) for field soils. The similarity of these figures eliminates the possibility of the difference in forest and field soil density being caused by difference in the actual weight of the soil material.

When the specific gravities of the different soils were tabulated and averaged, it was found that, in the upper 9 inches the average field soil was 15.3 per cent heavier than the average forest soil. In other words, the upper 9-inch layer of the average field soil was 15 per cent more dense and therefore relatively less porous than the average old-growth forest soil. The difference may be as much as 30 per cent in certain areas. Similar tests conducted in 36 second-growth forest areas in Ohio gave practically the same results. Apparently soil porosity is not lost by cutting provided that forest cover, forest litter, and natural forest conditions are maintained.

The question naturally arises, to what depth does the greater porosity of forest soils extend? Does the difference occur only at the immediate surface or is it distributed throughout the entire 9-inch profile? This point is significant in the survival of tree seedlings, because if the porosity extends to any considerable depth, seedling roots will be able to penetrate much easier and the percentage of survival will be greater. The important question as to difference in water-holding capacities of forested and cultivated areas would be clarified by knowledge of the extent of looseness below the surface.

To settle this question, specific-gravity tests were made in each of three successive 3-inch soil layers in old-growth woods and adjacent field sites. The upper 3 inches of the average field soil was found to be 43.13 per cent heavier than the similar soil layer of the average old-growth forest site adjacent. This difference is based entirely on the mineral soil below the litter and duff accumulation. Similarly, the average density of the 3 to 6-inch soil layer was 12.29 per cent greater in the case of field soils. In the 6 to 9-inch layer the difference in density was negligible.

From these comparisons it may be seen that the greatest difference in density between old-growth woods soil and field soil is in the upper 6 inches. But although the lower layer shows no difference by apparent specific gravity measurements, water-absorption experiments show that the lower layer absorbs water much more rapidly in woods than in field soil.

Water Absorption of Forest Soils. As a corollary to the measurements of apparent specific gravity, a series of water absorption tests were made in old-growth forest areas and adjacent fields. Brass tubes, 2 inches in diameter and 12 inches long, were forced into the soil to a constant depth of 3 cm. This depth proved sufficient to insure that the water would not flow up around the end. The rate of water absorption from these tubes was measured at the depths of 1, 3, and 8 inches. At the first depth, the litter or duff layer was removed. At the second or 3-inch depth, a trench 2 inches deep was dug before the tubes were inserted. At the lower depth, a trench 7 inches deep was dug. This procedure placed the bottoms of the brass tubes approximately 1, 3, and 8 inches below the soil surface.

The relative rates of water absorption in forest and field soils strengthen the conclusion drawn from the density measurements, that forest soils are more porous than field soils. At the 1-inch depth the forest soils absorbed water 50 times as readily as did the field soils; at the 3-inch depth the absorption by forest soils was nearly 15 times as rapid; even at the 8-inch depth, where no difference in soil density was apparent, absorption by forest soils was more than twice that of the field soils. Although these figures are only relative, they clearly indicate the tremendous water-holding capacity of a forested area in contrast to the resistance to absorption and therefore the rapid run-off from cleared lands.

Soil Porosity of Grazed and Ungrazed Woods. Nine second-growth forest sites were selected as typical of grazed and ungrazed woodlands. The grazed areas were in the last stages of forest degradation with only a few old trees, no reproduction, and a ground cover of weeds, grass, and sod. The upper 9-inch layer of the average grazed woodland soil was found to be 15 per cent heavier than the corresponding soil section in an adjacent similar ungrazed area. Excessive pasturing not only prevents tree reproduction but also makes forest exhaustion inevitable through compaction of the soil. The grazed soil is harder, holds less moisture, has poorer aeration, and its general tilth is much deteriorated.

Soil Porosity in Forest Plantations. The final phase of the soil porosity study deals with forest plantation sites. Does soil porosity return to old fields after planting? Thirteen forest plantations from 12 to 60 years of age were measured for soil porosity and compared with adjacent field sites. The difference in weight of the upper 9-inch layers showed that the field soil averaged 13.6 per cent heavier than similar layers of adjacent plantation soil. This difference may be considered to represent a gain in porosity since planting. Field observations show that as soon as a litter is established under a planted stand of trees the soil becomes more porous. The observation was also made that the soil of coniferous plantations gained more in porosity in a given time than did that of hardwoods.

Tests in forest plantation and adjacent field soils also demonstrated that plantation soils have a much greater water absorption capacity. The average rate for the plantation sites at the 1-inch depth was 107 cc per minute compared with 8 cc for the field site. At the 8-inch depth, the averages were 13 and 3 cc per minute for the plantation and field sites respectively. These differences in absorption capacity are in line with the density differences recorded and represent a gain in soil porosity for the plantation since planting.

Functions of Forest Litter. The influence of forest on soil is inseparably connected with forest litter, and the proper production and retention of adequate quantities and kinds of forest litter is dependent upon good silvicultural practice. In the Central States region the accumulation of litter is seldom more than 1 inch in depth. The leaf fall decomposes rapidly and adds its fertility to the soil. The forest litter is, however, of great importance in this region even though it does not accumulate to a great depth. It serves as an absorbent, acts as a mulch or insulation against rapid evaporation, prevents compaction of surface soil by impact of rain, decomposes and furnishes plant food, and serves as a medium for microbiological activities.

Structure of forest soil has been developed through long periods of time. Root penetration, expansion and contraction with changes in temperature and moisture content, and activities of worms, insects, and animals, tend to make soil porous. The forest is a builder and a preserver of soil porosity. The penetration of roots and their eventual decay leave the soil interpenetrated with tubelike cavities. The process of cropping, on the other hand, ultimately decreases soil porosity and favors erosion. The porosity preserved in forest soils by the covering of litter is largely lost in field soils by impact of rain and by the silting and illuviating action of percolating waters.

When the Central States region was settled originally, both good and poor lands were cleared and cultivated. The accumulation of organic matter in the form of incorporated and unincorporated forest litter afforded a temporary supply of plant food, and even the poorer, shallow soils produced well for a time. Then this food supply became exhausted and the land ceased to yield a reasonable return for its cultivation. As the organic matter was oxidized, plant food leached away, and the top soil eroded, the land became increasingly unproductive. The impoverishment under agricultural use of originally fertile forest soil became a major factor in the growth of land abandonment.

Forest Management. Virgin old-growth forests, except as a valuable means of interpreting optimum site conditions, are of no concern in the Central States region. The virgin woods are gone; only second-growth and abandoned fields remain. In the case of second-growth woodlands, careful cutting and consequent opening up of the stand does not destroy soil porosity, provided the forest cover is quickly reestablished, and the litter is not destroyed by fire or grazing. To a great extent soil porosity is an indication of site productivity.

The millions of acres of submarginal and abandoned lands suffering from soil erosion represent a problem of great concern in the Central States. Most of this area was once forested with hardwoods; now that its fertility is largely exhausted an extensive reforestation program is an essential measure of land use planning. The rule in the past on such lands has been to plant the species which formerly grew there naturally or to trust to nature to reseed the area, without realization that the abandoned and deteriorated field soil is usually incapable of permitting the reestablishment of the original tree species. Great difficulty has been experienced in getting hardwood plantations established on such lands; coniferous species, especially the yellow pines, are as a rule more successful. Hardwoods, with the possible exception of black locust, are not so able to survive the adverse conditions that occur in worn-out soil. Mixed planting of locust and native yellow pines is recommended.

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Jan. 15, 1934.

# A BLACK LOCUST VOLUME TABLE FOR CONTENT IN CUBIC FEET

Plantation BLACK LOCUST
(Robinia pseudoacacia, Linn)
Central Hardwood Region

L. F. Kellogg

1933

Entire stem less bark
Cubic Feet

| Diameter breast high | | Total Height of Tree in Feet | | | | | | | | | Basis: No. of Trees |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | |
| | | Volume in cubic feet | | | | | | | | | |
| Inches (o.b.) | (i.b.) | | | | | | | | | | |
| 1 | 0.8 | 0.04 | 0.07 | 0.09 | 0.11 | | | | | | 14 |
| 2 | 1.6 | 0.13 | 0.22 | 0.30 | 0.38 | 0.46 | | | | | 32 |
| 3 | 2.5 | 0.21 | 0.38 | 0.53 | 0.70 | 0.85 | 1.03 | | | | 34 |
| 4 | 3.3 | 0.36 | 0.62 | 0.90 | 1.21 | 1.50 | 1.78 | 2.07 | | | 37 |
| 5 | 4.1 | 0.49 | 0.96 | 1.39 | 1.84 | 2.30 | 2.73 | 3.07 | | | 42 |
| 6 | 5.0 | | 1.34 | 1.97 | 2.61 | 3.22 | 3.83 | 4.46 | 5.20 | | 45 |
| 7 | 5.8 | | 1.80 | 2.70 | 3.55 | 4.25 | 5.25 | 6.20 | 7.00 | 8.30 | 27 |
| 8 | 6.7 | | | 3.52 | 4.65 | 5.80 | 6.80 | 8.10 | 9.30 | 10.70 | 26 |
| 9 | 7.6 | | | 4.40 | 5.90 | 7.30 | 8.75 | 10.20 | 11.60 | 13.30 | 26 |
| 10 | 8.4 | | | 5.50 | 7.25 | 9.10 | 10.70 | 12.40 | 14.20 | 16.50 | 30 |
| 11 | 9.3 | | | 6.60 | 8.80 | 10.80 | 12.80 | 14.70 | 17.00 | 19.50 | 25 |
| 12 | 10.2 | | | 7.80 | 10.30 | 12.70 | 15.10 | 17.30 | 20.00 | 23.30 | 22 |
| 13 | 11.0 | | | 9.20 | 12.00 | 14.90 | 17.50 | 20.20 | 23.40 | 27.00 | 8 |
| 14 | 11.9 | | | | 13.80 | 17.00 | 20.20 | 23.30 | 26.70 | 31.00 | 6 |
| 15 | 12.8 | | | | 15.80 | 19.50 | 23.00 | 26,50 | 30.40 | 35.00 | 5 |
| 16 | 13.6 | | | | | 22.30 | 26.30 | 30.40 | 34.40 | 40.10 | 4 |
| 17 | 14.5 | | | | | 25.00 | 29.60 | 34.40 | 39.40 | 45.30 | 4 |
| 18 | 15.3 | | | | | | 33.70 | 38.90 | 45.00 | 52.00 | 4 |
| 19 | 16.2 | | | | | | 38.60 | 44.00 | 51.60 | 59.50 | 4 |
| 20 | 17.1 | | | | | | 44.00 | 50.70 | 59.00 | 68.00 | 1 |
| Basis: No. of Trees | | 18 | 53 | 65 | 44 | 90 | 39 | 43 | 29 | 15 | 396 |

Trees measured by Central States Forest Experiment Station in Indiana, Illinois, and Ohio. Stump ht. 1.0 ft. Volume measured by planimeter. Aggregate deviation: chart 0.01% high. Average percentage deviation on 393 trees, 9%. Block indicates extent of basic data. Prepared by the alinement chart method.

This is the first of several volume tables for plantation black locust. As other tables are completed they will be issued immediately in this form in order to avoid delay in making them available to those who need them.

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Oct. 1, 1933.

# GROWTH OF BLACK LOCUST

L. F. Kellogg
Associate Silviculturist

Black locust is reputed to grow very rapidly, and where conditions are most favorable, it does produce phenomenal growth. There is danger, however, of expecting more of this species than is justified. In a great majority of places where it has been and is likely to be planted, and particularly on most eroded lands, very high growth rates should not be expected. Except for limited localities (such as the belt of loessal and unconsolidated soils extending from northern Mississippi to the mouth of the Illinois River), locust used for erosion control must be expected to exhibit at best only average growth. Yield plot measurements made in some 250 plantations in Ohio, Indiana, Illinois, and western Kentucky and Tennessee may be used as a basis for approximating the growth of this species. Few plantings over 50 years of age were found and most of them were 30 or younger.

Growth in height varies directly with the quality of the site and is reduced by attacks of the borer. At 10 years of age on the poorest sites for locust, the dominant trees average only 15 feet high; on medium sites, about 30 feet high; and on the best sites, as high as 45 feet. At 25 years of age, the heights of the tallest trees on the poorest, average, and best sites are about 25 feet, 50 feet, and 70 feet, respectively. At 40 years, the heights run 30 feet, 60 feet, and 85 to 90 feet, respectively. Some natural sprout stands in the Appalachians have exceeded these heights by 10 to 20 feet. Sprout stands of locust ordinarily display straighter stems with less taper than do trees from planted seedlings.

A plantation in Jefferson County, Indiana, provides a typical example of a poor stand. Although it was 25 years old in 1932, the height of the tallest trees was only 32 feet. The tops were open and thin and growth was slow, averaging about 1.3 feet yearly. The stand allowed so much light to reach the ground that eastern red cedar reproduced beneath the locust. The stand was also badly attacked by the locust borer. In contrast, a 27-year-old plantation in Bartholomew County, Indiana, illustrates very good growth. The largest trees are 75 feet tall and 14 inches in diameter. Height growth has averaged about 2.8 feet a year.

Diameter growth also varies according to quality of the site, as is shown by the measurements secured in several typical 10-year-old plantations. On a very poor locust site in Tennessee the largest tree was 3 inches in diameter, but the average was only 1.6 inches; on a medium site in Illinois, some trees reached a diameter of 5 inches, but the average was 2.8 inches; on an excellent site in Indiana the largest dominant tree was 7 inches in diameter,

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and the stand averaged 4.4 inches. Measurements made in typical 25-year-old plantations located on a poor site in Ohio, on an average site in Indiana, and on an excellent site in Tennessee, recorded maximum diameters of 7, 10, and 13 inches, respectively; the average diameters for the same three plots were 4.1 inches, 6.0 inches, and 8.4 inches. On an excellent site in southern Indiana a40-year-old plantation produced trees from 8 to 17 inches in diameter, averaging 10.8 inches. Diameter growth is often erratic and distorted following severe locust borer attacks.

Time Required for Special Products. The various products, such as fence posts, insulator pins, wagon hubs, tree-nails, mine timbers, and poles, for which black locust is utilized, have been discussed at length by John B. Cuno in U.S.D.A. Circular 131 - The Utilization of Black Locust. All of these uses depend upon the qualities of durability, hardness, and strength possessed by the wood of this species. It becomes pertinent to know how soon various products can be secured from planted stands. Measurements of over 400 locust trees in plantations in Ohio, Indiana, and Illinois, for the construction of volume tables, provide a basis for determining these ages for locust sites, such as occur north of the Ohio River.

Fence Posts. Although very small posts are sometimes used for special purposes, the commercial fence post is usually 7 to 8 feet long, with a top diameter of 4 to 6 inches. Nothing less than a tree 5 inches in diameter at breast height will yield a standard post, and the most profitable production is from slightly larger trees, which will yield several posts each. Ordinarily it requires from 15 to 20 years to grow locust trees of standard post size. In instances of unusually good growth, a few of the dominant trees may reach the necessary size for posts at an earlier age, but they will be in the minority.

It has been frequently stated by various authorities that locust posts are produced at much earlier ages than those stated above, but analysis of these statements discloses that there is considerable difference of opinion as to what constitutes a post. The longevity and durability for which locust posts are noted cannot be expected from the use of small pieces, or from very rapidly grown trees in which the proportion of durable heart wood is low.

Bolts. For the manufacture of insulator pins, wagon hubs, and tree-nails, locust is cut and handled in bolt form. According to Cuno, bolts 5 to 7 inches in diameter just about carry the cost of production, whereas profitable manufacture comes from utilizing bolts 8 inches and over. Trees at least 10 inches in diameter are required to produce bolts of this size. On the best sites they can be grown in about 30 years, and on average sites in about 40 years. With further increase in the age and size of the trees, bolts will become larger and more profitable to manufacture. Consequently the stumpage value and yield also increase.

Volume and Yield Tables. Field data, previously referred to, have been secured for the construction of both volume and yield tables for black locust, but the publication of this emergency report could not be delayed until all tables were completed. They will be made available to supplement this report as they are completed.

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Oct. 1, 1933.

# SUGGESTIONS FOR LOCUST BORER CONTROL

By Ralph C. Hall, Assistant Entomologist, U. S. Bureau of Entomology

The Borer Problem is Increasing. Under the present Emergency Conservation Work program of erosion control, a very large acreage of black locust is being planted. On much of the poor quality land requiring planting, locust will make very poor growth, and as a result of slow growth will very likely be badly injured by the borer. We can expect the locust borer problem to become very acute in the Central States, unless precautions are taken to guard against it. The present planting program should be followed by one of protection and management of these areas. If this is not done, the locust borer problem will become increasingly serious, not only within these planted lands, but also on adjoining areas which at the present time have no problem. Unless controlled, the large acreage of slowly-growing locust may be expected to build up an enormous population of adult borers, resulting in widespread infestation.

In some regions erosion plantings probably will not create any additional borer problem, if we can judge from the plantations already established. These include certain areas in Tennessee, Illinois, and probably parts of Iowa having similar soil conditions. In general, it appears that deep soils which gully badly, such as the unconsolidated areas of Tennessee and Illinois and the loessial soils of this region, will produce much faster-growing locust than thin soils with an impervious subsoil, which tend more to sheet erosion. Thrifty, fast-growing locust suffers little from borer attack.

Description and Life History. The locust borer (Cyllene robiniae Forst.) is a very destructive forest and shade-tree insect widely distributed throughout the United States wherever black locust trees are abundant. Injury, caused by the larval or grub stage of this insect, consists of large burrows in the sapwood and heartwood of the trunk and larger branches of the tree, and often results in its death. Even though the locust borer may not kill trees outright, it often renders them unfit for useful products or disfigures them for ornamental purposes. Trees may be so badly weakened by this insect that a slight wind will cause them to break off at points of serious attack.

The presence of the young borer is easily detected in the early spring about the time the leaves begin to unfold. At this time characteristic brown or yellow pellets of excrement may be seen coming from "wet spots" (caused by the flow of sap) on the bark around the entrance to the larval galleries. Much of the injury is confined to the lower portions of the trunk where the bark is rough. Other signs of infestation consist of unopened leaf buds or dwarfed foliage. Old attacks are readily recognized by calloused swellings of growth on the trunk, by dead limbs, or by borer holes extending into the wood. Repeated attacks by the borer often kill the tree.

In the adult stage the insect is a comparatively large, long-horned beetle about three-fourths of an inch in length. It is deep velvet-black in color, marked with bands of bright yellow. The adult beetles occur in large

numbers on goldenrod in the late summer or early fall. The female adults deposit their eggs in the rough crevices of the bark of black locust, usually from the first part of September to the middle of October. The eggs hatch in about one week, and the young larvae, or grubs, bore their way through to the inner bark, where they pass the winter in a dormant state. Early in the spring, at about the time the buds begin to swell, they resume their activity and finally work into the woody portion of the tree. Up to this point in their life cycle there has been little damage to the tree, but the damage increases from this time until the larvae are full grown, because their work is now confined to the woody portion of the tree, often penetrating to the pith. The larvae reach full development during the month of August, at which time they pupate, emerging as adults during the latter part of August or in early September. The dates mentioned for the different stages in the life cycle apply to the Central States, but they will vary with different geographical locations, being earlier to the south and later to the north.

## FACTORS INFLUENCING AMOUNT OF BORER DAMAGE

During the past four years a comprehensive study of the locust borer has been conducted in the Central States. Some 500 sample plots of black locust have been established and studied. The major part of this work has been confined to Ohio and Indiana, but plots have also been established and observations made in Tennessee, Kentucky, Illinois, Iowa, Michigan, West Virginia, Pennsylvania, New York, and North Carolina. Hence practically all conditions of black locust growth and locust borer damage have been studied.

Tree Vigor. The results of this investigation have demonstrated that a very close relationship appears to exist between locust borer damage and the vigor of the tree. This relationship is an inverse one, with borer damage declining as vigor of the tree increases. This study has demonstrated further that, within stands of locust over ten years of age, a close relationship exists between crown class and locust borer injury, the dominant crown class suffering the least injury, and the overtopped class the most. In this respect it appears that thrifty trees are able to overcome attack, while slowly-growing, overtopped trees often succumb, or are so badly injured that they have no commercial value.

That thrifty tree growth is the cause, and not the effect, of relative immunity from locust borer damage, has been definitely shown by a survival study of young borer larvae. It has been determined that eggs are deposited indiscriminately on trees of all crown classes. In an average plantation there will be about as many eggs deposited on dominant and codominant trees as on those intermediate and overtopped. However, from the standpoint of survival of the larvae which hatch, a different condition exists, and the survival shows a definite relation to crown class. In the upper crown classes there will be practically no survival of young larvae which start in the spring, but in the lower crown classes the survival of young larvae may be very high, and on the average about 50 per cent will produce adults. From the standpoint of production of adult borers, then, the lower crown classes produce over 75 per cent of all the borers in most stands. The reason for the lower survival of larvae in the more thrifty trees has not been determined. Apparently it is coordinated with rate of growth, but the determining factor may be one of moisture relationship. This question is being studied on permanent sample plots at the present time.

Early Rate of Growth Indicates Probability of Attack. It appears that the rate of growth of a stand for the first four or five years may indicate to a large extent the probable ultimate injury by the locust borer. That is, if a stand of locust has difficulties in becoming established, and grows slowly during its early years, it is probable that the ultimate injury by the locust borer will be severe, because, when the slowly-growing locust is attacked, the survival of larvae will be very high, and as a consequence injury will be serious. However, if the early growth has been rapid, little ultimate injury will probably result, because there will be a low survival of larvae and consequently little injury. From the data collected on this phase of the study, it appears that it may be possible to predict the ultimate injury quite accurately from early growth. By using the average diameter and height growth of a stand as an index, we can predict what the probable injury to a stand will be, and in this way anticipate an attack and take steps to prevent it.

Shade. In his early work on the borer, Dr. F. C. Craighead pointed out that there appeared to be a close relationship between shade and locust borer attack. While the results of this later investigation have not entirely substantiated his theory, there appears to be a high degree of correlation between shade and locust borer injury. However, shade is apparently an effect rather than a cause. That is, in stands which have a dense shade and an unbroken crown canopy, there can have been little injury or death of trees, and consequently the crown density has not been reduced thereby. On the other hand, in stands which are severely injured by the borer, individual trees have been killed, and the resultant stand is only partially shaded.

Drought. Black locust endures lack of moisture better than most hardwood species, yet it may be severely damaged by excessive drying out of the soil. Drought is a factor which cannot be controlled, but it plays a very important role in locust borer damage, especially on certain soil types. These include excessively dry sites as well as soils having a heavy, impervious subsoil. Drought injury is often confused with locust borer injury, but differs in this respect: if injury is caused by extreme drought, practically every tree in the stand will show the effect, whereas injury caused by the borer will be more spotty, and even in instances of extreme attack some trees will be more severely injured than others.

Drought may so lower the resistance of a previously thrifty stand that the locust borer is able to develop successfully in trees which, before the drought, were not susceptible. A number of stands were observed in western Indiana where, as a result of the 1930 drought, this was true. In one instance a thrifty stand of locust, with site index 90, had no successful borer attack before the drought, but during the period following the drought, borers were able to complete their development, and as a result this stand is rapidly being killed. Other similar cases were noted in that same general area, especially on the heavier soils, where the drought injury was more severe. In many plantations the top of every tree had been killed. The effect of this 1930 drought on black locust was also noted in parts of Ohio and Illinois.

Fire. During its early life, while the bark is still smooth and thin, locust is very susceptible to fire damage. During this period even light surface fires may kill the trees, but in practically all cases the trees so killed will produce abundant sprouts. As the age of locust increases, it becomes more resistant to fire, and when mature will often withstand a severe fire. This

was observed to be the case in many of the Pennsylvania R. R. plantings in Pennsylvania and in several plantations in the Central States. The effect of fire in reducing the site quality is of great importance, for the inevitable result is decreased vigor of growth. Complete protection from fire should be provided on any area planted to black locust.

Grazing of Livestock. The detrimental effect of pasturing black locust stands may be both direct and indirect. The direct injury may result to young trees by cattle and sheep browsing the foliage and young succulent growth. When sheep and cattle have access to locust during the winter, they will often completely girdle the trees and cause their death. Sheep appear to be destructive to young locust, while cattle appear to do more damage to large trees. Trees up to 12 inches in diameter have been observed to have been killed. The indirect detrimental effect of pasturing black locust is that site quality is often greatly reduced by compaction of the soil. As has been mentioned previously, any factor which tends to reduce quality of site has an indirect effect upon locust borer injury.

## RECOMMENDATIONS FOR SILVICULTURAL METHODS OF CONTROL

In view of the close relationship which exists between tree vigor and locust borer injury, anything which can be done to increase the vigor of a stand will aid in minimizing injury. The treatment proposed for the control of the borer deals with four general types of stands: young, slowly-growing stands which will undoubtedly be severely injured by the locust borer; older stands which have been severely injured by the borer; older stands with only a moderate amount of injury; and stands in which black locust is mixed with other species.

Slowly-Growing Young Stands. The treatment proposed under this heading will be applicable to a high percentage of stands of locust which are being planted for erosion control, because many eroded sites will not support vigorous growth of the planted trees. A large number of instances have been observed during the progress of this study, where a planted stand of locust has grown slowly for the first few years and ultimately has been completely killed by borers. The trees so killed have, in practically every case, sprouted, and the resultant rapidly-growing sprouts have usually suffered very little from borer attack. Inasmuch as there is a high degree of probability that slowly-growing stands will eventually suffer serious borer attack, it is proposed to cut back these stands at an early age before any attack has started, and before there has been a chance for a large borer population to be built up. The more vigorous sprouts which follow this cutting might reasonably be expected to suffer less from the borer, due to the low survival of young larvae in them. This cutting should be made about four or five years after the trees have been planted, when the rate of growth will become evident. This treatment should be followed by a thinning in the sprout clumps, in which all but the best sprout in each group are removed.

Severely Injured Stands. It is proposed to clear-cut severely injured stands during the dormant period of growth, as suggested originally by Craighead, and depend upon regeneration by sprouts. There are numerous instances where such treatment has resulted in a good second crop of trees with very light subsequent injury. As in the preceding method, the resulting sprout stands should be thinned by the removal of all except the most thrifty sprouts.

Moderately Injured Stands. Inasmuch as it is the overtopped, intermediate, and weaker codominate trees in a stand which are borer producers, it appears that the removal of these trees in a thinning operation should greatly reduce the borer population and subsequent injury. It is also to be expected that such a thinning may tend to increase the vigor and rate of growth of the trees left, and in this manner make them better able to overcome attack by any remaining borers. A heavy thinning which might cause excessive and harmful exposure of the remaining trees or of the site, should of course be avoided.

Control by Mixed Planting. It is an accepted fact that a tree species grown in mixture with other trees usually suffers less from insects or other enemies than when grown in pure stands. Confirmation of this has been repeatedly observed in the case of black locust. When scattered among other trees the locusts are to some extent protected and shielded from attack by the borer, and at the same time their vigor of growth is usually increased by association with other species, provided that the intolerant locusts are not harmfully crowded or overtopped. The foliage of a pure stand of locust does not produce dense shade or an abundant leaf-litter, but when it is combined with the leaf-fall of other trees, a soil-protecting and building litter becomes established to increase the productive capacity of the site. In an environment conducive to vigorous growth, the danger of injury by the borer is decreased.

Sanitation Cuttings. Whenever locust is to be planted, it is advisable to make a survey of all the native and planted locust in the general vicinity, and remove all severely injured or decadent trees which might be serving as brood trees for the locust borer. In some sections of the Central States it is quite common to find old, decrepit trees with their tops stagheaded and partly broken, making ideal brood trees due to their general unhealthy condition. Infested trees should be cut during the dormant period and either burned or peeled to destroy the larvae.

## OTHER CONTROL

Natural Enemies. All previous investigations of the locust borer have indicated that there are few parasitic enemies of the larvae, and comparatively few predators on the adult, so far as is known. The present investigation has disclosed the fact that the downy woodpecker may be an important predator on the young larvae early in the spring. In one badly injured plantation, these birds devoured 85 per cent of the young locust borer larvae in less than a week. However, it appears that this was an unusual instance, because in no other area was a similar result noted. Woodpeckers occasionally destroy fully grown larvae and pupae in late summer, but as in the preceding case, their effect over large areas appears to be insignificant.

Spraying. The cost of direct control measures is usually prohibitive in large plantations, but may be warranted in the case of ornamental trees of small planted areas. The most effective is the use of crude orthodichlorobenzene spray solution. This is prepared as follows: make a stock solution of 1 gallon of orthodichlorobenzene, 1 gallon of soft water, and 1 pound of fish oil soap or common laundry soap. The soap is dissolved in boiling water, and after the mixture has cooled sufficiently, the ortho is added. To one part of stock solution add from three to six parts of soft water to make the spray solution. The spray should be applied to the trunk of the tree sufficiently to get complete coverage, especially from the ground line up to five or six feet. Early spring when the locust leaves are just beginning to unfold is the best time to spray.

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Station Note
No. 4

Oct. 1, 1933.

# SITE REQUIREMENTS OF BLACK LOCUST

By John T. Auten, Silviculturist.

Because black locust occurs naturally on many kinds of soil and is commonly found even on dry, infertile ridges, it has been classified generally as a species very indifferent to quality of site. From the standpoint of its ability to establish itself and exist, this is true, and therefore locust is admirably adapted for planting on eroded lands. From the standpoint of rapid growth, profitable yield of wood products, and resistance to locust borer attack, however, this conception of black locust site requirements must be very greatly modified. Like most other tree species, it makes its best growth on deep, fertile, moist but well-drained soils. Data gathered from the examination of more than one hundred plantation plots, selected for study throughout the Central States and in adjacent regions, provide for a better understanding of black locust's adaptability to various conditions of soil and site.

Soil Classification. Accurate and detailed soil surveys have been made for many counties of the Central States, and it might be expected that recommendations for planting black locust, or any other tree, might be based entirely upon soil classification. This assumption is only partially correct, for there are many local variations within a soil type that influence plant growth. Trees are sensitive to soil changes, particularly to local underground conditions affecting moisture and drainage, which cannot be shown on a soil type map.

For instance, the Clermont silt loam of southern Indiana is generally unfavorable to the best growth of black locust, but local areas occur where the subsoil conditions enable this species to grow very well. In general, the Tama silt loam of Iowa is favorable to locust growth, yet unfavorable local sites within this soil type are by no means uncommon. The physical factors of soil structure, condition of the subsoil, and drainage are very important in locust site determination, and may have far more influence on growth than fertility and other factors characteristic of a soil type. For this reason, any accurate classification of site must be made for each individual area in accordance with the requirements of the tree species.

Definition and explanation of several terms commonly used in soil science are necessary for a clear understanding of the discussion of site requirements of black locust.

Soil texture refers to the size of the particles, such as sand, silt, or clay. Texture may be determined readily by the feel when soils are rubbed in the hands: sands are gritty, pure silts are smooth without stickiness, and clays are slick and sticky when wet. Various combinations of these textures may be approximately evaluated.

Soil structure is the arrangement of the soil particles and is evidenced by porosity, compactness, and fracture. Soils with a loose, porous structure are composed of sponge-like lumps which crush readily and often feel gritty. Soils with a tight or dense structure are usually composed of hard, compact lumps which are difficult to crush in the hand, and break up into irregular, angular fragments. When wet, they feel slick and sticky; when cut with a knife they present a shiny, waxy surface, often with a mosaic appearance. Coarse textured soils usually have a loose structure which is favorable to tree growth, whereas fine textured soils often have a tight structure, which is unfavorable. Structure may undergo drastic changes. For instance, a virgin soil under a forest, with abundant organic matter and a protective cover of leaf litter, is generally loose and porous in structure; following clearing, excessive cultivation and cropping, with subsequent exposure, leaching and erosion, porosity is largely lost and the soil becomes compact and dense in structure. Loose soils are often severely compacted by the trampling of livestock.

A soil horizon is a horizontal layer of soil differentiated from that above or below in color, texture, or structure. A vertical section displays the soil profile, which is the arrangement of successive soil horizons, one over the other.

## FACTORS INFLUENCING LOCUST SITES

Soil Structure. Of all the physical properties of soil, that of structure apparently exerts the greatest influence upon tree growth. Compactness of a soil, particularly a tight subsoil, is invariably detrimental to the growth of black locust. A dense structure lessens water absorption and moisture-holding capacity, reduces drainage and aeration, and makes the penetration of roots very difficult. It has been observed repeatedly that locust roots grow downward to a tight soil horizon and there stop, rarely penetrating it. If this tight subsoil lies only a foot or two below the surface, the top soil remains undrained and excessively wet during rainy periods, and becomes abnormally dry during periods of drought. Either condition is unfavorable to the optimum growth of black locust. On the other hand, a loose, porous structure is conducive to drainage and aeration and permits what has been termed rootilation - that is, tubular porosity caused by the penetration of the roots and fine rootlets. As a result of their penetration and decay over long periods of time, such a soil becomes sponge-like.

Color of Subsoil and Its Significance. The color of the subsoil in itself is probably not important, but it is an indication of a very significant condition: namely, its state of aeration, drainage, and oxidation. The surface of the soil water-table fluctuates between fairly definite levels during the year. The submersion level is the point where much of the finer soil material is deposited from above by illuviation. This action over long periods of time creates a tight subsoil layer. As deposition and tightening increase, air has more difficulty in penetrating the soil, and a reduced condition develops. A reduced soil is likely to be drab or blue in color because of reduced oxides, whereas an aerated or oxidized soil is likely to be brown or red-brown because of the higher state of oxidation. Trees need oxygen in the soil for important nutritive processes and the state of oxidation may be judged roughly by observance of soil color.

A scale of colors used in the examination of soil profiles proves very helpful in the determination of sites suitable or otherwise for the growth of locust. The scale is as follows:

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|---|---|
| 1. Red-brown | - Excellent site |
| 2. Yellow-brown | - Very good site |
| 3. Brown-yellow | - Good site |
| 4. Yellow | - Medium site |
| 5. Drab and Yellow | - Medium site |
| 6. Drab and blue | - Poor site |
| 7. Blue | - Very poor site |

This scale applies particularly to the subsoil because the subsoil seems to be the critical horizon as far as locust growth is concerned. The better sites were almost invariably found on soils having brown or reddish-brown subsoils. Soils having drab or drab and blue subsoils were practically always poor sites, regardless of the condition of the topsoil.

Drainage. Good soil drainage is necessary for the best locust growth. Any soil which does not permit free removal of surface water, a condition that commonly occurs on flat areas of tight soils and on low lands, is not suited to good locust growth. Such a soil remains wet and cold in the spring and is likely to become excessively dry and baked in the summer. A poorly-drained soil does not permit enough air to enter to allow for proper decomposition of organic material and adequate elaboration of plant food.

A dry, exposed sandy or shale ridge with excessive drainage likewise offers a poor site for locust, although it may exist there and grow slowly. Sandy soil, however, may be excellent if the water table is near the surface, or if the site is on a sheltered slope where seepage from above supplies the needed moisture. Sand soils as a rule become very dry during periods of drought and locust will not flourish in any soil which dries out excessively. Following the previous discussion of subsoil color, it must be remembered that sand soils are likely to be brown in color, well oxidized and drained, yet they may be poor sites because of extreme dryness. The same is likely to apply also to shallow soils over rock or shale.

Aspect and exposure influence site quality. A southern exposure may induce dryness of site unfavorable to locust growth, and the prevalence of strong winds on an exposed ridge frequently has a detrimental influence.

Soil Fertility. Fertile soils with abundant organic matter and necessary mineral elements available for plant growth, naturally provide the best sites for black locust, if the physical properties of the soil are also favorable. This study has clearly established the fact that soil fertility alone is no final criterion of locust site quality. The best locust stands were not always found on the most fertile sites, as judged from the agricultural viewpoint; some of the poorest stands were found on soils whose surface was very fertile. A loose, light soil of inferior fertility may provide a site much better than a black, fertile topsoil underlain with a tight subsoil. The presence of organic matter is undoubtedly helpful in supplying plant food, in holding moisture, and in improving the structure of the surface soil; but if the moisture relationships of the site are upset by a clay-pan, or by a dense, waxy clay subsoil of poor structure, organic matter on the surface will not ensure good locust growth.

After two seasons' field work and observations of black locust stands, it has not been established that soil reaction is an important influence on site quality. Investigations included electrometric measurements in the field of some 500 soil horizons, and the conclusion reached is that there is no apparent correlation between site quality and soil acidity or alkalinity. Good sites were found on both acid and sweet soils; likewise poor sites were found on limestone and siliceous soils. A similar lack of correlation with soil reaction was found by Dr. A. G. Chapman of Ohio State University in his investigation of nitrogen-fixing nodules on the roots of black locust.

The Influence of Erosion on Site. The foregoing discussion of soils and sites favorable or otherwise to black locust will prove helpful to tree planters whose primary purpose is the growing of profitable crops of this species. In planting locust for erosion control, however, the planter is forced to accept a given site which may prove unfavorable to that species. Even in such instances it has been shown that the use of this tree, usually in mixture with other species, is advisable.

In the past, tree planters have been told that it is usually safe to plant native trees which formerly occupied the site, or which grow well on nearby lands of a similar character. Studies of forest sites in the Central States have now shown that this is not always a safe rule to follow. Following the clearing and cultivation of forest lands, changes in soil due to erosion, leaching and excessive cropping often result in sites very unfavorable to tree growth. In some localities erosion quickly removes loose surface soil and the exposed surface becomes compacted by rain and clogging of the soil pores. In many instances the topsoil is entirely washed away and only the subsoil is left. Such a condition makes the establishment of young trees very difficult or impossible. Seedlings are exposed to the hot summer sun on a soil surface that bakes and cracks. Under such conditions even black locust, which endures such hardships better than most other hardwood species, has difficulties in surviving.

On the other hand, there are extensive areas of deep, unconsolidated or loessal soils where erosion is usually very severe, and yet the quality of the site for black locust has apparently been little impaired. This study has shown that site quality is not dependent in a large measure upon the thickness of the surface soil horizon, provided that subsoil, drainage, and other conditions are favorable. From the data of surface horizon thicknesses measured on 116 plantations, site quality indexes for the same sites failed to show any correlation. This does not mean that eroded land is as good as it was before the surface horizon was washed off, but it does show that the effect of a tight under-horizon is so significant that mere thickness of the surface soil is of secondary importance. A soil may have a 24-inch upper horizon - black, fertile and loose; but if under it is a tight clay horizon, the site may be poorer than one with a 2-inch upper horizon and a friable, well-aerated subsoil horizon. Fortunately hilly land, where erosion is most severe, usually has a fairly well oxidized and aerated subsoil. It has natural drainage and is seldom water-logged.

Locust will make some growth on nearly any soil, and from the standpoint of its use for erosion control, this is very fortunate; but if profitable returns from locust products are the chief consideration for planting, the site must be as carefully selected as for many other species.

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Revised
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# BLACK LOCUST PLANTING FOR EROSION CONTROL

By L. F. Kellogg, Associate Silviculturist

The value of forest cover on non-agricultural lands for erosion control has been definitely established, but in many regions a combination of improved agricultural practices, the establishment of gully-dams or other engineering works, and the planting of forest trees are all necessary to solve the erosion problem. Where erosion is not severe - or where it is confined largely to moderate sheet washing -- terracing, contour plowing, cover crops, and other improved methods of agriculture may suffice for control. A sod cover is often effective and under favorable conditions may be used for pasture, if not overgrazed. In many instances, however, pasturing tends to reduce the effectiveness of grass cover, and to increase erosion.

On steep slopes or on very erosive soils a permanent cover of forest trees is often the most successful means of preventing excessive run-off of water and severe erosion. The soils of many localities have been so severely impoverished by past cultivation, leaching and washing, that only a forest cover may be established and maintained economically. Furthermore, a forest not only holds the soil in place very effectively by the binding action of tree roots and by the protective cover of leaf litter, but it also increases the porosity and water absorption capacity of the soil (1)*, improves its fertility, provides refuge for game, birds, and other wild life, and produces profitable forest crops, which, if harvested properly, may be removed periodically without sacrificing the protective value of the cover.

Where gullying is very severe, check dams also may be of benefit in erosion control. Their construction and use have been described in a number of publications, some of which (5) (7) (9) are referred to in Literature Cited, page 5, so that no attempt is made to cover this subject in this report.

Black locust is particularly well adapted for erosion planting. It establishes itself readily even on poor, dry sites such as are found on abandoned farm lands throughout the Central States. In such an environment locust may not be expected to make good growth, and it often succumbs at an early age to locust borer attack, but it holds the soil temporarily, thus providing an opportunity for other trees, plants or grasses to become established. Numerous suckers and sprouts appear wherever the rapidly spreading roots become cut or injured in any way, as by subsequent erosion, and add to the protective value of the cover. The investigations of Chapman (2), McIntyre and Jeffries (4) demonstrate the beneficial effect of black locust in improving the site and stimulating the growth of associated trees by the fixation of nitrogen.

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*Numbers in parentheses refer to Literature Cited, page 5

Black locust seed is relatively cheap and readily obtainable in large quantities, although the present practice of depending largely upon foreign sources of seed is of doubtful wisdom (3). The seedlings grow very rapidly and may be planted out after a few months to a year in the seedbed. When nursery stock is not available, root sprouts or root cuttings may be used for emergency planting. Black locust grows very rapidly on the better soils, where injury from locust borers is generally lower, and soon produces valuable crops of fence posts or other products of great strength and durability. It seeds abundantly at an early age and reproduces prolifically.

The recommendations regarding the planting of black locust which follow are the result of numerous observations of the success or failure of many plantations established by different agencies under a variety of conditions, largely on a trial and error basis. Much necessary information is still lacking because of the piecemeal manner in which these observations were obtained. Many of the unsuccessful black locust plantings have disappeared so completely that the lessons to be learned from them have been entirely lost. A comprehensive and well-coordinated study of forest planting and plantations must be completed before many final conclusions can be drawn.

Spacing. The usual spacing recommended for black locust plantations is 6 feet by 6 feet, or 1,210 trees per acre. On steep, badly eroding slopes closer spacing with trees 3 or 4 feet apart may sometimes be desirable, to bind the soil in place as quickly as possible. On level land where washing is not severe, a wider spacing with trees 8 feet apart (680 per acre) is less costly and often results in satisfactory control of the erosion. The sprouting habit of locust, wherever the spreading roots are uncovered, bruised or torn, usually insures a full stand of trees on eroding land, even where comparatively wide spacing is used. Root suckers can be stimulated artificially in young plantings by breaking the roots with a plow or disc.

Regular spacing is generally inadvisable on the steep sides and rough bottoms of gullies. Advantage should be taken of the more sheltered and favorable spots where the trees are most likely to become established promptly and securely. Trees planted in gully bottoms directly behind check dams are in danger of being covered with the washed-in soil unless planting is delayed until the terrace is well established. For the same reason the rims and steeper slopes of the gullies should be plowed down or otherwise reduced before planting. It is advisable to replace trees which die, to secure a complete cover.

Mixture of Species. The many advantages of planting mixed stands of two or more tree species are well recognized. In mixed forests the dangers of loss from insects, disease, and other enemies are much reduced; soil and site conditions are improved; wood production is usually increased; the silvical and biological environment of the artificial forest becomes balanced and approaches that of the natural forest, a very desirable condition. For these reasons, the planting of other tree species with black locust is highly recommended, especially where wood products, other than those yielded by locust, are wanted. Moreover, on soils poorly adapted to the successful growth of black locust, or where excessive damage by the locust borer is practically a certainty, it is usually safer to plant some other species in mixture. On such sites the use of locust is recommended only because of the prompt establishment of this species and its soil-binding and soil-building values.

In the past there has been so little planting of locust in mixture with other species that there are few examples upon which to base recommendations. R. C. Hall has found that mixtures of locust with catalpa have not displayed a reduction of borer infestation as in mixtures with other hardwoods. Plantations of black locust with a volunteer understory of hard maple have been found to form a very excellent mixture, yielding high protective value and an excellent forest litter. A native mixture of locust, red maple, red oak, black cherry, and black oak has been found to develop a good litter and a good stand. Yellow poplar is often found mixed with locust in natural stands on good sites. Throughout the unglaciated, southern portions of the Central States, shortleaf, pitch, and Virginia pine are possibly adapted for planting on eroded lands with black locust. Present knowledge indicates that the pines should be given a start ahead of the locust, possibly 2-5 years. In this region few successful mixtures of locust with northern or exotic conifers have been found. Native hardwoods should be used only on the better and more fertile soils. Wherever hardwoods volunteer, they should be encouraged as a component of the stand.

Very little is known on the best methods of making mixed plantings. One method of mixing species is to plant alternate trees of the various kinds. Alternate rows of a single species, or planting groups of a single species may possibly succeed. The latter method may apply particularly where there are local variations of site favorable to a single species and unfavorable to others. Since locust is intolerant of shade, it will not thrive if it is subjected to serious overtopping or crowding by associated species.

Planting Methods. The best time for planting is early spring before growth starts, although fall planting is also resorted to, especially in the South. Seedlings planted in the fall may be subject to frost heaving during the following winter, especially in northern regions and on exposed slopes. Mattocks are commonly preferred for setting the trees, but heavy spades or dibbles may be used in light soils free from stones. Occasionally it is desirable to plow the area in order to prepare the site to the best advantage and to facilitate planting. Where it is unnecessary or undesirable to plow the entire area, planting in plowed furrows is recommended. It is essential to keep the roots moist at all times, and they should be evenly distributed and spread out in the planting hole. Cultivation of the tree rows is sometimes practiced for the first year or two, but such cultural methods are not generally necessary. Meginnes (8) considers cultivation of distinct advantage in increasing growth in height and leaf surface and in reducing damage by leaf miners. On severely eroded areas further disturbance of the soil or its vegetative cover by plowing or cultivation is often undesirable.

The plantation should be adequate in size to anchor the sides and head of the gully. This calls for the extension of the planting operations out around the wash for a width of at least 15 or 20 feet. Unless the margins of the gully are bound with the fibrous locust rootlets, it may continue to extend back into adjacent field or pasture land. Very often the entire field or surrounding areas in which the gully occurs is in danger of subsequent erosion and, therefore, unsuited for agricultural cultivation. In such instances the wisest and best land use is to grow a cover crop of trees.

Planting Stock - Nursery Seedlings. Most State forestry departments have established nurseries which produce tree seedlings for planting on State or other public lands; trees are also available, usually by purchase at a nominal price, for private planters. Some commercial tree nurseries produce forest planting stock. It is very unwise to ship in stock from a distance, because of the danger of importing and spreading some active disease on the stock. Since locust seedlings are easily grown in one year's time, the establishment of a home nursery is recommended for planters who can secure stock in no other way or who wish to raise their supply (6).

One-year-old seedlings, from 12 to 18 inches in height above the ground, are usually preferred for planting in the Central States, although larger stock is sometimes recommended for use in the South. Seedlings smaller than this usually lack the sturdiness essential for rapid establishment, and larger stock is both difficult to handle and costly to plant. Where climatic and soil conditions are favorable, seedlings sometimes grow several feet in height in the nursery in one year's time. To overcome such undesirable height growth, the planting of the seeds in the nursery beds is often delayed until late spring or early summer. In the Tennessee State Forest nursery, black locust seedlings are kept down to an 8 or 10-inch size for convenient handling by mowing off their tops in the seedbed with a tractor-drawn machine, and similarly the stock is root-pruned in the seedbed to eliminate excessively long root systems.

So far as size is concerned, good seedlings of one season's growth in the nursery are ready for either fall or spring planting. Seedlings or transplants over one year of age are usually too large for successful and economical planting in this region. When seedlings are too large, or where conditions of climate or site are unfavorable to their establishment after planting, it is usually advisable to cut back the stems to a point a few inches above the ground. This may be done as the seedlings are dug in the nursery, or just before or immediately after they are planted.

Other Sources of Planting Stock. When nursery seedlings are not available, stock suitable for emergency erosion planting may be secured from other sources. Many successful locust plantations for posts have been established by the use of small sprouts or root suckers dug locally around healthy, well-formed trees. If the roots from which the suckers are obtained are well provided with fibrous rootlets, they can be dug and immediately replanted, preferably in the early spring. Lacking these rootlets, the sprout should be prepared for removal a year in advance, by cutting the main root off a few inches from either side of the sprout. This treatment forces the development of the necessary rootlets.

Root cuttings from 6 to 10 inches long and from $\frac{1}{2}$ to 1 inch thick may also be used to establish black locust. Toumey (10) states that the cuttings should be made in the fall or winter and planted immediately or wrapped in moss and stored in a cool, moist cellar. The process of storing develops a callous at the cut ends and stimulates the production of buds. Ordinarily they should be held in the nursery for one year before being planted in the field. An experimental planting of fresh forest root cuttings in Illinois blow-sand by Dr. Hall of this Station developed vigorous sprouts, but the tops were killed back by the severe summer drouth of 1933.

Direct seeding of black locust for the control of gullies is not advisable. Without previous treatment, the seed is very slow to germinate, and raw soil conditions in eroded gullies are seldom favorable for vigorous, rapid growth of tiny seedlings. In addition, the likelihood of the seed's being washed away, buried deeply, or consumed by rodents and birds, makes direct seeding a hazardous and undesirable method of establishing black locust.

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# EXTRACTION OF BLACK LOCUST SEED

By Leonard F. Kellogg, Associate Silviculturist.

Increased demands for nursery stock for erosion control planting under the Emergency Conservation Work program has brought about a shortage of seed of black locust (Robinia pseudoacacia Linn.) from the usual commercial sources. Therefore, many forestry agencies are wisely engaged in collecting their own supply locally. To answer inquiries regarding the best methods of extracting black locust seeds quickly and economically from the dried pods, several tests of available apparatus have been recently made by the Central States Forest Experiment Station. The results of this necessarily hastily conducted investigation are reported for the benefit of those who are now engaged in locust seed collection without previous experience in this work.

An ordinary commercial pea-sheller, of the type commonly used in canneries and at Agricultural Experiment Stations, was first tested. About a peck of old last-year's pods were fed through it and apparently the seed was easily knocked loose. Screening separated the seed and dirt from the pods, and winnowing before an electric fan blew out the dirt and foreign matter. A second test, using recently-picked but dried pods which had matured this year, resulted in removal of only about 25 per cent of the seed. The seed was of excellent quality, however, and unbroken. From this test it is concluded that the pea-sheller may give good results with old, thoroughly dried pods, but is not efficient in the extraction of seed from recently matured pods.

A clover-huller was next tested, on a threshing job where a separator with a clover-huller attachment was in operation. Only one ounce of locust seeds per bushel of pods were obtained from this machine. The balance were ground up like chicken-feed. The clover-huller is designed to scarify seed in threshing, to aid in germination. With the removal of the corrugated concaves, adjustments as to their numbers and spacing, or substitution of wooden slats, this machine might prove more successful in locust seed extraction.

The next trial utilized a small, 22-inch threshing separator with concaves set for wheat, with very satisfactory results. A scant half-bushel of locust pods yielded 12½ ounces of seed with little breakage. It is believed that any similar standard-size threshing separator may be readily adjusted, after testing with a half-bushel or so of pods, to give equally good results.

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It was found necessary to run the pods through the machine twice to secure complete separation. Pods must be fed to the cylinder slowly; rapid feeding results in the pods slipping between the pegs without being opened or threshed. A hand-feed, rather than a mechanical feed, is required. The air must be practically cut off from the blower, because an air current strong enough to blow out the pods will carry the small locust seeds with them. It is suggested that threshing be done on a clean, tight floor, from which the numerous seeds that escape from the machine during threshing may be swept together and salvaged.

The mixture of pods and seeds was next run through a "Clipper" fanning mill to separate the seeds. The top screen was #14 (3 holes per inch) and the bottom screen was #7 (6 holes per inch). Perhaps a #8 screen would give better results, since the #7 screen did not permit a few of the larger seeds to pass through.

It is believed that a competent thresher might be able, by substituting screens, by adjusting concaves, and by careful regulation of the speed of his machine, to work out an efficient method of extracting and cleaning locust seed in one operation.

Lack of time and a sufficient quantity of locust pods for these tests prevented the acquiring of any valuable data as to the relative costs of these methods of locust seed extraction.

The use of an old-fashioned flail for threshing black locust seed has been suggested, but this method was not tested. It would probably prove satisfactory for a small quantity of pods.

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CENTRAL STATES FOREST EXPERIMENT STATION

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# COLLECTION OF BLACK LOCUST SEED

By John G. Kuenzel, Junior Forester.

Local Seed Collection Urged. Black locust (Robinia pseudoacacia Linn.) occupies an important place in erosion control planting under the Emergency Conservation Work program. There are indications that the commercial supply of black locust seed is rapidly dwindling and many forest nurseries may be unable to purchase quantities sufficient for their needs. Instead of depending entirely upon European and outside sources, those in charge of forest nurseries are urged to gather at least part of their locust seed supply locally this fall. The use of planting stock from local seed is always preferable to taking a chance with foreign seed, and the use of ECW or other forest labor now provides excellent opportunities for seed collection. For those who have had little or no experience in gathering black locust seed, the following suggestions are offered.

Time of Collection. In the Central States black locust seed normally ripens early in September, although this year some seed was mature late in August. The pods should not be gathered before the seed has thoroughly matured and hardened. They may be collected until late in the fall or early winter, although as the ripened pods dry out on the tree they open and some seed is dropped from time to time. Therefore, early collection is desirable.

Choice of Seed Trees. Seed is no better than the parent tree. It is strongly urged that pods be collected from healthy, thrifty, well-formed trees. No seed should be collected from very young trees and from those under 18 - 20 feet in height. The experience of Dr. Hall has indicated that pods collected from the lower branches contain only about 40% as many viable seeds as those from the upper portions of the crown. Care should be taken to select trees bearing the current year's crop. Some trees retain the pods from the previous year, in which the seed is usually withered, moldy and infertile.

Method of Collection. Seed can be collected most economically where it is available on trees that have been felled immediately after the seed ripened. Where felled trees are not available, the pods must be gathered from standing trees.

With the use of a ladder a tree climber can hand-pick the pods growing near the trunk and on the lower limbs, but he is unable to collect those

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from the top of the tree and the outer branches with safety. A good collector can gather about a bushel of pods per day, which should yield from one to two pounds of seed. A sack of closely woven fabric slung across the climber's body by means of a stout cord provides a satisfactory pod container. Gauntlets help to protect his hands and wrists from thorns.

With the use of an ordinary long-handled tree-pruner, the climber can reach the pods much more readily and with greater safety. As he cuts the small bunches of pods from the outer and upper branches, a man on the ground gathers them and clips the pods into a basket with a pair of hand-pruning shears. In this manner two men are able to gather several bushels of pods in a day.

After collection, the pods should be stored in a cool, dry place until they can be threshed. Good ventilation of air and scattering the pods is necessary to prevent molding. A tight floor will prevent the loss of the seeds that escape from the pods during the period of storage.